GRADUATE STUDY AND
RESEARCH IN CIVIL AND
SANITARY ENGINEERING

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Contents

THREE-MILLION-POUND TESTING MACHINE. The large machine centered in the four-story structural testing laboratory has a capacity of 3,000,000 pounds in both tension and compression. This view shows a connection on a large bridge-type member that has been tested as a part of a program to evaluate the effect of the arrangement of the rivets or bolts on the strength of the member. Maximum load on the specimen was about 800,000 pounds.
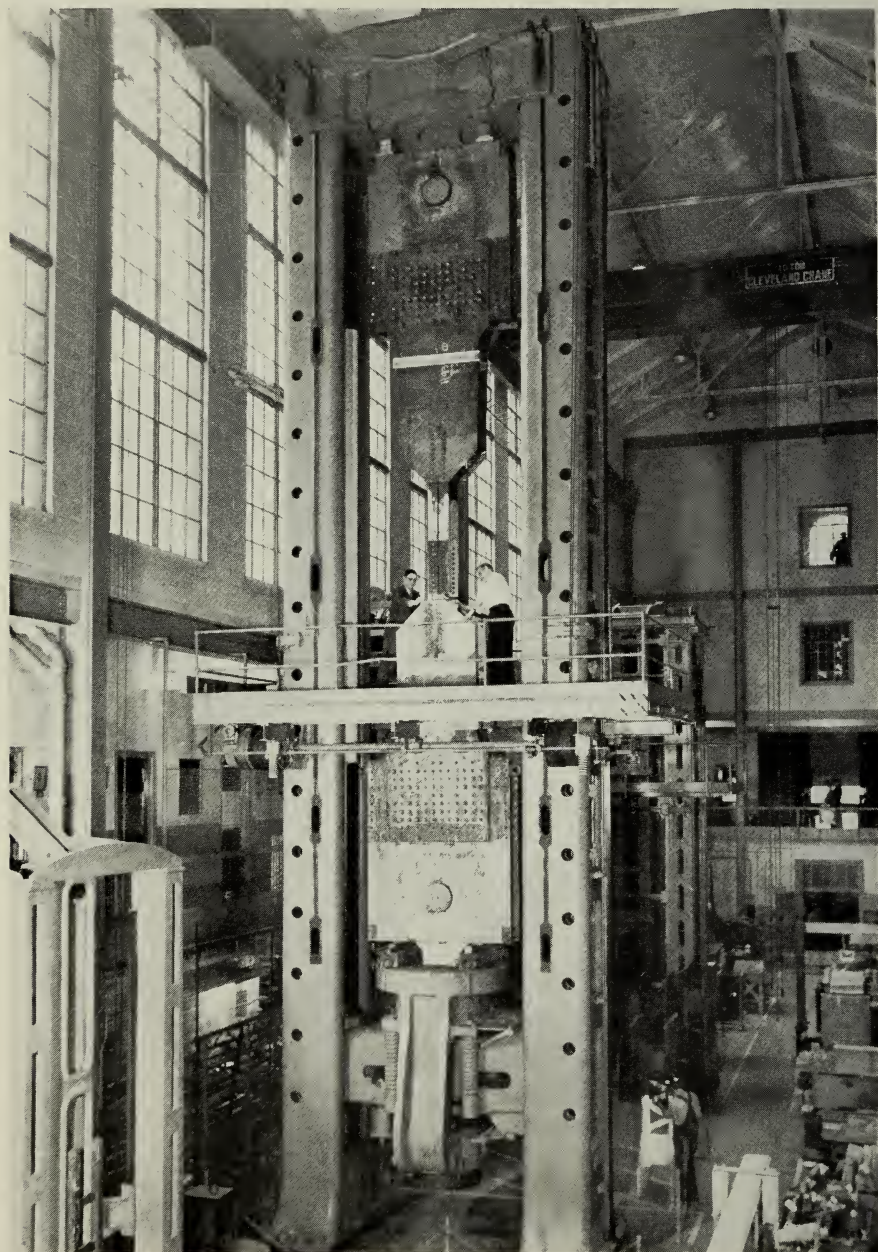
Graduate Faculty in Civil Engineering
and Sanitary Engineering

WILLIAM C. ACKERMANN, B.S., Professor of Civil Engineering and Chief of State Water Survey

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RALPH BRAZELTON PECK, D.C.E., Professor of Foundation Engineering

ARTHUR RICHARD ROBINSON, Ph.D., Associate Professor of Civil Engineering

MILTON OTTO SCHMIDT, Ph.D., Professor of Civil Engineering

CHESTER PAUL SIESS, Ph.D., Professor of Civil Engineering

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General Comments

This pamphlet has been prepared especially for students considering graduate study in civil engineering and sanitary engineering at the University of Illinois.[1] More complete information may be found in the catalog of the Graduate College, copies of which may be obtained by writing to that college. Any regulations and requirements included in the Graduate College catalog, but not in this pamphlet, apply to all graduate students including those in Civil Engineering and Sanitary Engineering.

The Department of Civil Engineering offers advanced study and professional training in the general fields of highway engineering, hydraulic engineering, railway engineering, sanitary engineering, soil mechanics and foundations, structural engineering, geodetic and photogrammetric engineering, and traffic engineering. Facilities for research are available in all these fields, and active research programs directed by members of the staff are under way. In programs of graduate study emphasis is placed on both course work and research.

The degrees of Master of Science and Doctor of Philosophy may be attained by qualified students who satisfy the requirements of the department and the Graduate College. Progress toward an advanced degree is measured not only by the accumulation of units of credit in formal course work but also by evidence of intellectual growth and achievement.

The main purpose of graduate study is to enable a student to broaden his knowledge of and increase his competence in a given field. Graduate study, especially in the second and third years of the doctorate, aims at the development of independent scholarship, originality, and competence in research.

About 265 students from all parts of the world are enrolled in the graduate programs in Civil Engineering. Because of this enrollment, it is possible to offer a wide range of courses on all phases of civil and sanitary engineering. Also, the many foreign students bring to the Department a variety of experience which broadens the outlook of all who are included in the graduate group.

The extensive research program involving an annual expenditure of approximately one and one-quarter million dollars creates an atmosphere of research and enables students to participate in and come in contact with active research projects. Research is supported by the University as a part of its educational program for undergraduate and graduate students. However, a large part of the research program is supported by special grants from various sponsors including federal and state agencies, technical

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[1] Students contemplating graduate studies are encouraged to procure a copy of the pamphlet entitled "The Road to Graduate Study," available from the American Society for Engineering Education, University of Illinois, Urbana, Illinois.

societies, professional associations, and research councils. Present sponsors are:

American Institute of Steel Construction
American Iron and Steel Institute
American Society for Testing Materials
Association of American Railroads
Caterpillar Tractor Company
Chicago Bridge and Iron Foundation
Cities Service Athabasca, Ltd.
Commonwealth Edison Company
Defense Atomic Support Agency
Department of the Air Force: Directorate of Civil Engineering; Directorate of Intelligence; Special Weapons Center
Department of the Army: Corps of Engineers; Office of the Chief of Engineers
Department of Commerce: Bureau of Public Roads
Department of Health, Education, and Welfare: Public Health Service
Department of the Navy: Bureau of Ships; Bureau of Yards and Docks; Office of Naval Research
Engineering Foundation
General Services Administration: Public Buildings Service
Gregory Industries, Inc.
Metropolitan Sanitary District of Greater Chicago
National Academy of Science-National Research Council: A.A.S.H.O. Road Test; Ship Structure Committee
National Lime Association
National Science Foundation
National Steel Corporation
Portland Cement Association
Reinforced Concrete Research Council
Research Council on Riveted and Bolted Structural Joints
State of Illinois: Division of Highways
United States Steel Corporation
Welding Research Council

Importance of Graduate Study

The increasing complexity of many phases of engineering and recent scientific and industrial developments have created a strong demand for civil and sanitary engineers with training beyond that included in undergraduate programs of study. Among the fields of work for which graduate study is desirable and for which it prepares the engineer are: advanced analysis and design; consulting engineering practice; teaching of both fundamental and advanced courses in civil engineering and related fields; research

and development in industrial laboratories, educational and scientific institutions, and governmental agencies; and administrative responsibilities in various specialized fields.

Formal graduate course work and participation in creative research enables the civil engineer with graduate training to go beyond the limitations of present practices and to contribute to the progress of his profession.

Admission

Applications for admission are processed by the Dean of Admissions and Records. Application forms can be obtained from the Graduate College, the Office of Admissions and Records, or the Department of Civil Engineering. A qualified applicant can be admitted at any time, but in order to avoid delays, a prospective student is urged to submit his application at least six weeks in advance of the opening of the session in which he plans to enroll. An official transcript from each undergraduate college attended must be sent to the Dean of Admissions and Records. In addition, all grad-

TRAFFIC SIGNAL DEMONSTRATION PANEL. This panel, one of the items of equipment in the traffic engineering laboratory, is used to demonstrate the operation and application of different types of traffic signal equipment. Student solutions to signal design and timing problems may also be verified on the panel.
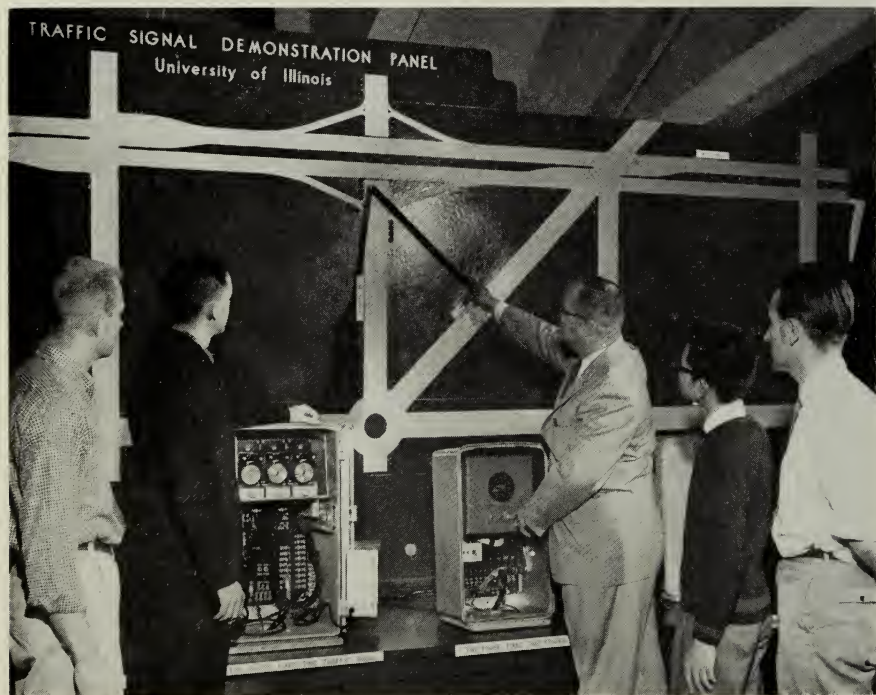
uate students entering graduate study in the Department of Civil Engineering, except those who have applied for financial assistance, must arrange to have one additional set of transcripts forwarded to the department office for its records and use. Transcripts of students who enter the Graduate College can not be returned.

The general requirements governing admission as as follows:

Admission to the Graduate College with full status in civil or sanitary engineering is granted to graduates of institutions whose requirements for the bachelor's degree are substantially equivalent to those of the University of Illinois, provided the applicant's preparation is appropriate to advanced study in his chosen major field and his scholastic average is at least 4.0.[1] This average is computed on the basis of the last sixty semester hours of credit recorded.[2] Under certain conditions applicants with a grade-point average of less than 4.0, and applicants from schools with different grading systems, may be considered if their average is at least the equivalent of 3.75 and evidence is submitted indicating that the applicant's ability is not appropriately measured by the grades submitted. Evidence that the school's grading system is based on a different datum will be considered. Such applicants should have their application accompanied by at least two letters of recommendation regarding their ability, and by such other evidence that they wish to submit. Only outstanding students in this category are admitted.

Beginning in the fall of 1960, all new graduate students entering the University of Illinois are required to take the Graduate Record Examination, usually during their first semester of residence. Students who have recently taken the examination and whose test results are available, are not required to take the examination.

Admission to graduate courses may be granted only to those who have had the requisite undergraduate work in those courses. Students whose preparation is considered inadequate may be required to take without credit certain undergraduate courses.

Upon arrival on the campus, all foreign students from non-English speaking countries are required to take a comprehensive examination in the use of the English language. Depending on the results of this examination, the student may be required to take and pass certain rhetoric courses as a requirement for obtaining an advanced degree from the University of Illinois. In such cases the student must expect to spend at least an extra semester or summer session before receiving his degree.

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[1] In converting to a numerical grade, the following equivalents are used: A = 5; B = 4; C = 3; D (minimum passing grade) = 2.

[2] All hours of credit are included for all courses in the semesters, quarters, or summer sessions involved in the last sixty hours of undergraduate work and accordingly the total of hours used in the average may be greater than sixty. Courses failed and subsequently passed must also be included.

Upon the recommendation of the head of the department and with the approval of the Dean of the Graduate College, admission with advanced standing is granted to applicants who have completed a master's degree or the equivalent elsewhere and who desire to become candidates for the doctor's degree at the University of Illinois. A candidate for admission with advanced standing must meet the minimum standards noted above for entering graduates, and must exhibit an excellent record in his advanced work. The department desires, and may require, that a student supply in support of his application for advanced standing an official record of his aptitude and advanced standing in the Graduate Record Examination administered by the Educational Testing Service, Princeton, New Jersey. The record supplied must be for an examination taken during the preceding year.

The amount of credit to be accumulated at the University of Illinois before the candidate can be admitted to the preliminary examination can be determined only by the advisers in the major and minor fields after the student has registered and completed some work here.

Registration and Program of Studies

Registration. Dates for registration in the Graduate College are shown in the calendar, a copy of which will be sent upon request. Registration for the first semester is scheduled for the middle of September; that for the second semester, the second week of February; and that for the summer session, the middle of June. A former student who registers late must pay a late registration fee of $5.00. The registration of a new student is accepted at any time, provided he is prepared to enter courses already under way for credit reduced in proportion to the length of time which has elapsed since instruction began. He is not charged the late registration fee.

A graduate student obtains a program card and other registration material from the department office during scheduled registration days or at any time thereafter. The student should then consult his departmental adviser as explained below. The adviser suggests the courses of study and, in the case of a new student, determines the deficiencies, if any, that must be made up. These deficiencies are listed on a prerequisite blank; if there are no deficiencies, the adviser so indicates on this form. When the program card has been approved by the adviser, the student secures on it the signatures of the individual instructors in whose courses he is enrolled. After securing these signatures the student returns to the department office to have his registration tallied. The adviser provides each student with a Graduate Information Card which the student must fill out and return to the department office when he has his registration tallied. The student then goes to the English Building to obtain the remainder of his registration cards and instructions for the completion of registration.

Advisers. Every graduate student must have an adviser who assists in planning and carrying through a program of graduate work which fits the needs of the student and satisfies departmental and Graduate College requirements. New graduate students are interviewed by the head of the department who assigns an adviser in the student's major field of interest. The adviser for research assistants is normally the staff member in charge of the assistant's research program.

Unit Credit for Courses. Courses offering graduate credit are numbered from 300 to 399 when they are open to advanced undergraduates and to graduate students, and are numbered 400 and above when they are open to graduate students only.

Graduate credit is measured in terms of units. One unit is considered the equivalent of four semester hours. The normal program for a full-time graduate student is four units each semester; the maximum permissible is five. The normal program for an eight-week summer term is two units; the maximum of two and one-half units may be carried only with the approval of the adviser.

The amount of credit which may be earned in individual courses is

TEST OF REINFORCED CONCRETE FLOOR SLAB. A one-quarter scale model of a flat-plate type reinforced concrete floor slab with nine five-foot square panels tested as part of a program to determine the relative strength and behavior of various types of reinforced concrete floor slabs for buildings. This view shows a research assistant mounting electrical strain gages prior to application of loads.
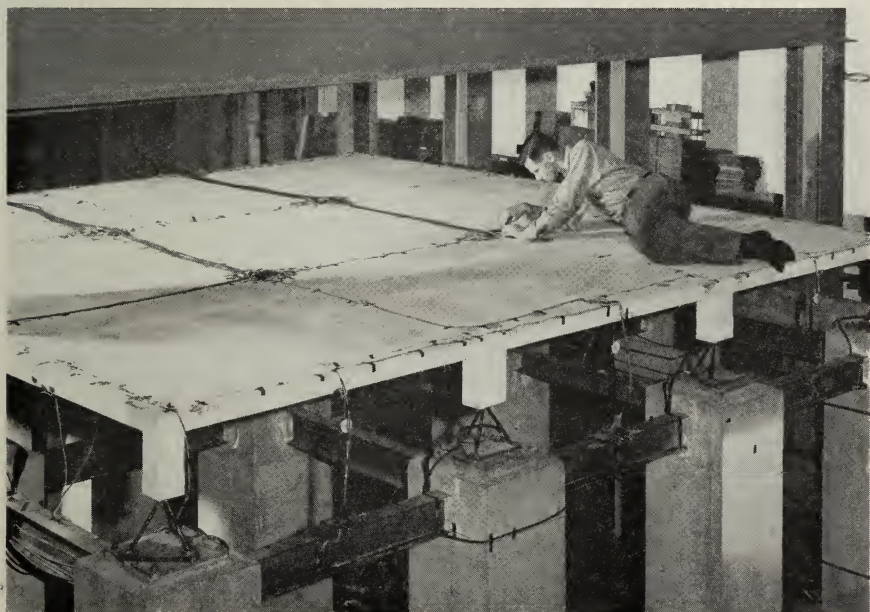
indicated in the course listing and is in some instances variable. The credit for which the student is actually registered in every specific course is entered on the student's program card by his adviser and is subject to the approval of the Dean of the Graduate College.

Miscellaneous Courses. A graduate student carrying a normal graduate program may elect, in addition, one miscellaneous course (a course which does not give credit toward an advanced degree). If a graduate student enrolls for more than one miscellaneous course, he may not register for a full graduate program. Courses intended to teach graduate students a reading knowledge of French, German, or Russian are regarded as miscellaneous courses. A student who elects a miscellaneous course is required to register in it and do the assigned work.

Auditing Privileges. A graduate student is permitted to attend classes (other than laboratory courses) as an auditor, provided a form bearing the approval of the instructor and the Dean of the Graduate College is filed with the Recorder. A student should not enter on his program card any courses he plans to attend as an auditor.

Graduate Programs for Employed Students. A student who is employed can not expect to complete his academic work as promptly as one who devotes full time to his academic program.

The academic work carried by assistants and others on the University staff is limited by statute. Those employed outside the University are expected to reduce their programs of work in accordance with these regulations. The maximum amount of academic work is determined by the terms of employment as follows:

	Maximum Registration	
Nature of Appointment	*Semester*	*Summer Session*
Full time	1 unit	1 unit
Three-fourths time......................	2 units	1½ units
Two-thirds time	2¼ units	1½ units
One-half time	3 units	1¾ units
One-third time	3½ units	2 units
One-fourth time	4 units	2 units

Under special circumstances additional thesis or research credit may be obtained.

Time Limit for Advanced Degrees.

1. A candidate for the master's degree must complete all requirements for the degree within five calendar years after his first registration in the Graduate College.

2. A candidate for the doctor's degree must complete all requirements for this degree within seven calendar years after his first registration in the Graduate College, except as noted in paragraph 3 on the following page.

3. A candidate for the doctorate who has received a master's degree elsewhere must complete all requirements for the degree within five years after his first registration in the Graduate College. This same regulation applies to the candidate who has received his master's degree from the University of Illinois and whose studies were interrupted immediately thereafter, provided not more than the minimum number of units required for the master's degree are applied to the doctorate.

4. In general, the transfer of graduate credit from other institutions under circumstances not specifically defined above shall be considered a basis for proportionate reduction of the time allowed for earning a degree.

Graduate Study in the Summer. During the summer session, a student may take courses for credit toward higher degrees, subject to the residence requirements listed below. The normal program for a summer term is two units; two and one-half units may be carried with the approval of the adviser. In no case is a student permitted to carry more than two and one-half units.

A limited number of civil engineering graduate courses are offered during the summer session. The fields included are usually structures and soil mechanics and foundations. The courses offered vary from summer to summer, so that by careful planning, it is possible to complete the requirements for the master's degree by summer study and make progress toward the doctor's degree.

Students from Abroad. A student from abroad who wishes to be admitted for graduate study at the University of Illinois should write to the Office of Admissions and Records, enclosing copies of his academic records certified by the educational institutions previously attended.

A student whose native tongue is not English is required to take an examination in English before registration. If his command of the language is not adequate, he must take and pass certain courses in the study of English as a foreign language, but credit earned is not applicable to an advanced degree. *In this case the student can not carry a full program of academic work and it will take relatively longer to complete the requirements for the degree desired.*

Immigration requirements demand that a foreign student admitted to this country as a non-quota student must register each semester for not less than three units of work if he is enrolled in the Graduate College.

The Office of Foreign Student Affairs assists foreign students with problems involving passports, visas, and other matters.

Grades. Grades are recorded by letters as follows: for courses, A (excellent), B, C, D, E (failure); for thesis research, S and U (satisfactory and unsatisfactory). Any student who receives two or more units of grade below B must replace them with additional units of A or B grade to

qualify for an advanced degree. Three units of a grade below B disqualify a student as a candidate for a degree in the Graduate College.

Petitions. The normal procedures and requirements of the Graduate College are indicated in this pamphlet, but these may be modified occasionally for justifiable reasons. A student may petition to the Dean of the Graduate College for exceptions, but he should do so only after consultation with his adviser. Forms may be secured at the Graduate College office.

Residence. Each degree candidate must spend a certain period of time in "residence." Residence is realized when a student lives in the community, or its immediate surroundings, and devotes an appreciable fraction of his time to graduate studies. A student who is employed outside the Champaign-Urbana community is not considered to be in residence even though he is registered in a campus course.

The Degree of Master of Science

The degree of Master of Science is offered in the fields of Civil Engineering and Sanitary Engineering.

Credit Requirements. A candidate for the master's degree must complete at least eight units of graduate work with satisfactory grades. Three of the eight units must be in courses numbered in the 400 series, and two of these three must be in the major field. When a thesis is not elected or required, the candidate must present at least nine units of course work.

Residence Requirements. A candidate for the master's degree must spend at least two semesters in residence and must earn at least half of the required units in residence. Attendance during four summer sessions in each of which the student is registered for not less than one unit of work, or in one semester with not less than two units and two summer sessions with not less than one unit each, is regarded as the equivalent of two semesters in residence. Registration for more than two units in a regular semester, or for more than one unit in a summer session, does not shorten the time which must be spent to discharge the residence requirement.

Work Done Elsewhere. A graduate student who has done graduate work in other approved institutions may petition to obtain credit, not to exceed four units, toward the master's degree by passing examinations in that work. Admission to such examinations requires the prior approval of the Dean of the Graduate College. The acceptance of credit for work completed elsewhere does not reduce the residence requirement of two semesters.

If it is recommended in advance by the adviser, the Graduate College may permit a student to register for work at a laboratory elsewhere offering facilities not available at Urbana, or in approved field work, with the

understanding that such work will be accepted for graduate credit if completed satisfactorily. The adviser examines the student's transcript and examines the student directly when he returns to this campus and then makes a final recommendation to the Dean of the Graduate College concerning the credit to be given.

Majors and Minors. A candidate for a master's degree may do all his work in one field, or he may select a major and one minor, or a major and two minors. A major or minor denotes the field of knowledge of a department, or such part thereof as constitutes a separate and independent division of that field. For a master's degree a major comprises work totaling a minimum of four units. Less than one unit of work does not satisfy the requirements for a minor.

Foreign Language. During the first year of graduate study a student who plans to become a candidate for the Doctor of Philosophy degree should qualify in at least one of the languages required by the Graduate College.

Thesis. If a student elects to prepare a master's thesis or is required to do so by the department, he should file the subject of the thesis at the Graduate College office at least six weeks prior to graduation. No more than three units of thesis credit may be included in an eight-unit program. Credit in thesis research can not be applied to a degree unless a thesis is submitted.

HYDRAULIC MODEL TESTING. A model of the sluice gates in the powerhouse at Lockport, Illinois, is being tested at the Hydraulic Engineering Laboratory for the purpose of calibrating the flow through the prototype structure.
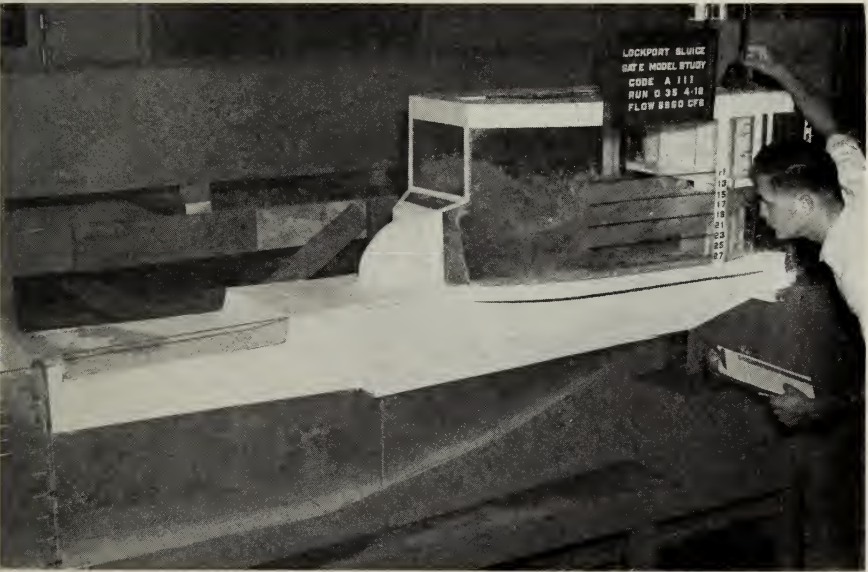
When a thesis is not elected or required, the candidate must present at least nine units of course work.

For specific instructions with reference to the preparation and form of the thesis, the students should obtain at the Graduate College office a copy of the leaflet "Instructions for Preparation of Theses." Two copies of the thesis with Certificate of Approval must be presented to the Graduate College office by the date specified in the calendar of the Graduate College. Candidates are expected to prepare at least four copies of the thesis. The original and first carbon must be deposited in the Graduate College; the other two are for the major department and the author. The Certificate of Approval for the master's thesis must be signed by the person under whose immediate supervision the thesis was prepared and also by the head of the major department. Blank certificate forms can be obtained at the Graduate College office.

Thesis Work on Leave of Absence. A student who has completed six units of course work in residence and who wishes to complete the thesis in absentia should consult first with his adviser. If the request meets with the latter's approval, a petition is submitted. The petition must include an outline of the proposed investigation and evidence that adequate facilities for pursuing it are available. If the work is to be done in an industrial laboratory, it is necessary to secure a letter from the company releasing to the University all patent and publication rights.

Suggested Programs. Suggested programs in the various fields in Civil and Sanitary Engineering are presented on page 47.

Conferring of Degrees. The master's degree is conferred in February, June, August, and October. Each student is responsible for entering on his registration cards, during the registration period preceding the time at which he expects to be awarded his degree, the fact that he is a candidate for a degree to be awarded at the end of that semester. If the candidate is not currently registered in the Graduate College, he must present his application to receive a degree at the Graduate College office no later than the final date specified by that college.

Not later than one week before the degree is conferred, each candidate for an advanced degree must obtain a clearance paper from the Graduate College. The student must obtain all the signatures called for on the form and return it to the Graduate College.

The Degree of Doctor of Philosophy

The degree of Doctor of Philosophy is offered in the fields of Civil Engineering and Sanitary Engineering.

Residence Requirements. For the degree of Doctor of Philosophy, the candidate must spend two years in residence, including two successive semes-

ters after the master's degree or the equivalent, and must complete at least sixteen units in residence.

Majors and Minors. A candidate is required to declare a major field of study and one minor (requiring four units) or two minors (requiring two units each). If he elects two minors, only one of them may be a division of the major department or field; a full minor must be entirely outside the department offering the major. The requirements for a minor in any field should be checked with the department concerned.

Language Requirements. A candidate is required to demonstrate ability to read two of the following languages: French, German, or Russian. The language requirement should be satisfied early in the doctoral program, in any event not later than two months prior to the preliminary examination, or during the semester (or summer session) preceding admission to the preliminary examination. A student may satisfy the language requirement by direct examination or by obtaining grades of A or B in French, German, or Russian 401. The dates of the language examinations and the latest dates when application for admission to these examinations may be made are shown in the University calendar (see Graduate College catalog). Certification of proficiency in foreign languages is not accepted from other colleges or universities.

Doctoral Committee. A permanent doctoral committee to conduct the preliminary and final examinations is appointed by the Dean of the Graduate College upon recommendation of the executive officer of the department in which the student is doing his major work.

Preliminary Examination. A candidate for the doctor's degree must pass a preliminary oral examination to test his knowledge of his major and minor fields of study. He is not admitted to the examination before (1) he has fulfilled the language requirement; (2) he has satisfactorily completed sixteen units of graduate work; and (3) the departments of his major and minor fields of study consider, through written examination or otherwise, that he has adequate preparation.

Final Examination. When the thesis has been completed, if the major department so recommends, the candidate is given a final oral examination by his doctoral committee. A student who has failed to maintain high standards of scholarship and research is refused admission to the final examination. Although the examination is concerned primarily with the research accomplished by the student as described in his thesis, it may extend over the candidate's whole field of study.

Latest dates for final examinations of candidates for degrees in February, June, and October are shown in the University calendar (see Graduate College catalog).

Thesis. The Doctor of Philosophy is primarily a research degree and

the candidate must demonstrate his capacity for independent research by the production of an original thesis on a topic within his major field of study. The subject of the thesis must be reported to the doctoral committee and to the Graduate College at the time of the preliminary examination. The student should register for at least eight units of research credit while preparing his dissertation. Moreover, after passing his preliminary examination, he must register each semester (excluding summer sessions) until such time as he passes the final examination irrespective of how many units he may have earned.

Directions regarding thesis form and style are given in the leaflet "Instructions for Preparation of Theses," copies of which may be obtained in the Graduate College office. The candidate must submit to the Graduate College, no later than the date specified in the current calendar, the original and first carbon (or two copies reproduced by an approved method) of his thesis and one typewritten copy of an abstract of not more than six hundred words. In addition, at least one copy must be presented to the major department and one copy should be retained by the author.

Each candidate who passes the final examination must pay a $25.00 fee. This provides for (1) microfilming of the complete thesis, with one copy deposited in the University of Illinois Library, and (2) publication of the abstract in *Dissertation Abstracts*.

Conferring of Degrees. The doctor's degree is conferred in February, June, and October. Not later than one week before the degree is to be conferred, each candidate for an advanced degree must obtain a clearance paper from the Graduate College office. The candidate must obtain all the signatures called for on the form, and then return it to the Graduate College.

Financial Assistance

Various types of financial assistance are available each year to promising graduate students. Detailed information about the qualifications and application procedures for these awards is given in the brochure "Financial Aid for Graduate Students," a copy of which may be obtained by writing to the Graduate College or to the Department of Civil Engineering. To be considered for a fellowship (except National Science Foundation Cooperative), research assistantship, or tuition and fee waiver for the following academic year, the application and all supporting material must be returned by February 15.

The principal kinds of awards are as follows:

Fellowships

University Fellowships. University fellowships are awarded on the basis of an all-University competition and are unrestricted as to the student's

field of graduate study. Each provides a tax-free stipend of not less than $1,500 for the academic year with exemption from tuition and all fees for the academic year and for the following eight-week summer session. University fellows must carry a full program, four units or the equivalent.

University Teaching Fellowships. These appointments provide a tax-free fellowship stipend of $1,000 plus a taxable salary of $1,000 for service as a quarter-time teaching assistant, with the usual exemption from tuition and incidental fees. University teaching fellows also carry full programs of graduate study, although their teaching duties may make it desirable to modify their academic program slightly.

Industrial Fellowships. A number of fellowships provided by industrial firms or foundations are available in several areas of study in Civil Engineering. Present sponsors of such fellowships and the areas of study are:

Automotive Safety Foundation: Traffic Engineering

California Oil Company: Structural Engineering or Soil Mechanics and Foundations

Esso Research and Engineering Company: Structural Engineering

Raymond Concrete Pile Company (in Memorial to A. E. Cummings): Soil Mechanics and Foundation Engineering

National Science Foundation Cooperative Graduate Fellowships. These fellowships are financed by the National Science Foundation, but are administered with the cooperation of the University. They are restricted to citizens of the United States who are graduate students in engineering sciences (or certain other sciences). Each carries a stipend of $2,200 for twelve months or $1,650 for nine months, plus tuition and fees. The University is authorized to appoint any of these fellows as a part-time teaching assistant with compensation not to exceed $800 for a fellow on twelve-month tenure or $600 for a fellow on nine-month tenure.

An applicant for a cooperative fellowship must send his application to the University, not directly to the National Science Foundation. Application materials may be secured from the Graduate College, the Department of Civil Engineering, or the National Science Foundation. The deadline date for filing applications is usually the first week in November.

Tuition and Fee Waivers. These awards provide exemption from tuition and all fees except the hospital-medical-surgical insurance fee for the academic year and the following summer session. In general, students holding these awards must be in residence and must register for at least three units each semester during the academic year. They may, however, accept part-time or incidental employment not to exceed twenty hours a week either within or outside the University.

Selection of Fellows. Fellows are selected by the Graduate Fellowship

Committee on the basis of scholarship and promise in teaching or research. All applicants are informed of the disposition of their applications on or about April 1. Successful applicants are expected to accept or decline by April 15. (See statement of policy adopted by the Association of American Universities on page 22.)

Departmental Requirement for Fellows. The department requests that all students holding first-year fellowships arrange to write a master's thesis or at least take one unit of special problems involving a comprehensive report on an individual investigation. This phase of the program provides the student with valuable training and serves as a guide to the department in making decisions about continuing studies, stipends, etc. Also, whenever possible, fellows are encouraged to associate themselves with the department's research program in order to broaden their training. In the case of fellows this must necessarily be done on a nonremunerative basis.

Assistantships

Research Assistantships in the Engineering Experiment Station. The Engineering Experiment Station is devoted to the study of problems of special importance to engineering and to the stimulation and elevation of engineering education. By undertaking a line of graduate study in close association with some one of the projects carried on in the Station, the student comes into contact with aspects of his specialty which he would rarely touch in a purely academic study, and thus broadens his outlook. The Experiment Station makes available apparatus, equipment, and the services of machinists, which materially facilitate the carrying on of investigations.

Half-time research assistantships, with a stipend of at least $2,000 for an academic year of two semesters, are open to graduates of approved technical colleges and universities. Applicants to whom these assistantships are awarded devote one-half of their time to the work of the Engineering Experiment Station and one-half to graduate studies. Each appointment is made for one academic year and normally are extended for a second year to permit the requirements for the master's degree to be satisfied. At the end of this period, if all requirements have been met, the degree of Master of Science is conferred. In general, with a half-time assistantship, two academic years of residence are required in order to obtain the master's degree. In addition, half-time or full-time work at a comparable rate for two and one-half months is usually available during the summer months. Thus, with an academic year half-time and a summer full-time appointment an assistant's annual stipend during the first year can be $3,110, plus exemption from tuition and fees during the academic year. Generally a commitment for a summer appointment can not be made in advance of the spring term preceding the summer session. A limited number of appointments are avail-

able, with prior arrangement, that permit completion of work for the master's degree by attending two consecutive summer sessions and the two regular semesters between them, or alternatively in three regular semesters.

Appointments to research assistantships are made only to students with outstanding records or other excellent qualifications. Appointments are given to first-year and second-year graduate students, but only rarely to third-year students who have not previously studied at Illinois. Study toward the degree of Doctor of Philosophy also may be pursued by research assistants who have already received a master's degree and who satisfy the requirements of the department and the Graduate College.

Students holding academic appointments requiring service for more than 62.5 per cent time are required to pay tuition and fees. Those whose appointments call for a lesser percentage of time receive exemption from tuition and all fees except the hospital-medical-surgical insurance fee.

A number of research assistantships in Civil and Sanitary Engineering are available. They include assistantships established by the University, and others provided by cooperative research agreements with state and

NISTRI PHOTOCARTOGRAPH V. This instrument, located in the photogrammetric laboratory, is a three-projector spatial aerotriangulator and stereoplotter of first order accuracy based on direct optical projection. It is suitable for plotting from aerial and terrestrial photographs in the whole range of cartographic scales and permits the use of both normal and wide-angle cameras. It is also capable of providing additional control points in sparsely controlled areas.
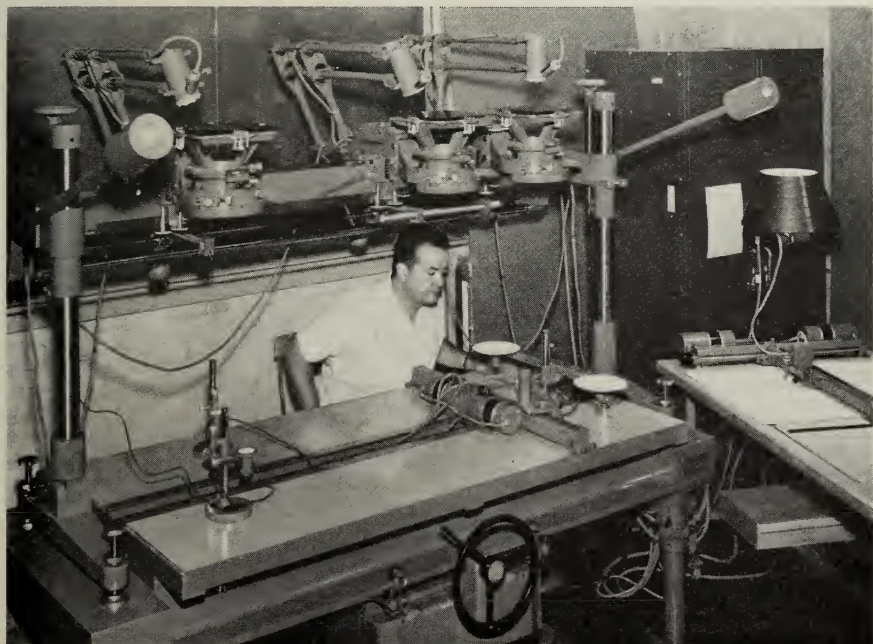
federal agencies, technical societies, and engineering associations. Two half-time University research assistantships designated as the Terzaghi Assistantships are reserved for students primarily interested in soil mechanics.

Fields of research now active include steel, concrete, and wood structures, theory and analysis, structural dynamics, structural welding, soil mechanics, foundations, retaining walls, culverts, earth dams, highway and traffic engineering, hydraulic engineering, photogrammetric engineering, and sanitary engineering. Most programs have both experimental and analytical phases, and in general both aspects are combined in each project in order to permit broader training. It is usually possible to assign a research assistant to a project in the field of his special interest. A thesis or research report is required at the master's level for all research assistants. Often the research in which he is engaged forms the basis of his thesis, but his thesis is not restricted to this field.

Applications for research assistantships should be made to the Head of the Department of Civil Engineering, preferably not later than February 15 to be considered for appointments effective the following September. Applications received after this date will be considered for any vacancies that may still exist. Although most appointments are made for the academic year beginning in September, some appointments may also be available in February or June.

Teaching Assistantships. In general the department does not grant teaching assistantships to new graduate students. The normal procedure is to select the teaching assistants from among the research assistants who have served as such for at least one semester. Prospective graduate students who are interested in teaching should apply for a regular research assistantship and subsequently make their desires known to the head of the department.

Other Financial Aids

Occasionally the department has other openings, as for example, Title IV Fellowships under the National Defense Education Act. Also, a number of other sources of support are available from outside agencies, as for example, the National Science Foundation and the American Society of Civil Engineers. Students are encouraged to apply for such stipends.

Acceptance Agreement

The University of Illinois adheres to the following resolution adopted by the members of the Association of American Universities and a number of other graduate schools of North America:

"In every case in which a graduate assistantship, scholarship, or fellowship for the next academic year is offered to an actual or a prospective graduate student, the student, if he indicates his acceptance before April

15, will still have complete freedom through April 15 to reconsider his acceptance and to accept another fellowship, scholarship, or graduate assistantship. He has committed himself, however, not to resign an appointment after this date unless he is formally released from it."

Fees and Expenses

Students registering for resident work pay fees each semester or summer session according to the following schedules:

SEMESTER TUITION AND FEES

(Payable in full when the student registers unless the installment plan is elected)

Tuition Fee (except those holding fellowships)

	Regular Schedule (Over two units)	Reduced Schedule (Two units or less)
Residents of Illinois	$ 75.00	$24.00 per unit
Nonresidents of Illinois	250.00	80.00 per unit
Laboratory, Library, and Supply Fee	12.00	6.00
Hospital-Medical-Surgical Insurance Fee	8.00	8.00

All students, including persons on part-time appointment on the University staff or the staffs of the allied surveys or laboratories, are subject to this fee. Students who present evidence of participation in any other group insurance system providing the same benefits as those covered by the University fee may petition through the University insurance office for a refund of this fee. *Students registered for one unit or less are exempt from this fee upon application to the University insurance office.*

| **Illini Union Service Charge** | 10.00 | 10.00 |

Students registered for one unit or less, holders of graduate tuition and fee waivers, and University staff members are exempt from this fee.

SUMMER SESSION TUITION AND FEES

(Payable in full when the student registers unless the installment plan is elected)

Tuition Fee (except those holding fellowships)

	Regular Schedule (Over one unit)	Reduced Schedule (One unit or less)
Residents of Illinois	$ 37.50	$24.00 per unit
Nonresidents of Illinois	125.00	80.00 per unit
Laboratory, Library, and Supply Fee	6.00	3.00

	Regular Schedule (Over one unit)	Reduced Schedule (One unit or less)
Hospital-Medical-Surgical Insurance Fee......	4.00	4.00

Students registered for one-half unit or less are exempt from this fee upon application to the University insurance office.

Illini Union Service Charge..................	5.00	5.00

Students registered for one-half unit or less and University staff members are exempt from this fee.

SPECIAL FEES

Late Registration Fee...$ 5.00

Former students, whether on appointment or not, who register after the regular registration days in either semester are subject to this fee.

Change of Program Fee.. 1.00

This fee is charged for every change slip issued at the request of the student after the completion of registration.

"In Absentia" Registration

Students enrolled for credit in thesis work for the master's or doctor's degree on leave of absence pay only the regular tuition fee, resident or nonresident, as listed above.

Registration for 0 Credit

Candidates for the doctor's degree, resident or nonresident, enrolled in thesis-research work for 0 credit pay each semester a flat fee of......... 6.00

Listener's Fee 10.00

Persons who attend classes as listeners, except those on University appointment and students registered for a full schedule, pay this fee for each course.

Transcript Fee 1.00

Each student who has paid all his University fees is entitled to receive, without charge, one transcript of his record. For each additional transcript the fee is $1.00.

Installment Fee 2.00

Students electing the installment plan for payment of tuition and fees must pay this service charge.

EXEMPTION FROM FEES

Certain graduate students may register in University courses for which they are eligible for admission without payment of the tuition fee and the laboratory, library, and supply fee. See the Graduate College catalog for details.

Housing

The University has residence facilities for single graduate students, both men and women, and a limited number of apartments in University-owned

student-staff apartment buildings. Applications for both rooms and apartments may be obtained from the Housing Division. In addition, the Director of Housing maintains a list of apartments and rooms available in private homes in the community.

Buildings and Equipment

The teaching and research activities of the Department of Civil Engineering are conducted in large portions of two major buildings — Civil Engineering Hall and Talbot Laboratory — and completely occupy several smaller buildings, including the Sanitary Engineering Laboratory, the Surveying Building, the Hydraulic Engineering Laboratory, and the Test Track Building.

Civil Engineering Hall. This building, with a floor area of 64,000 square feet, houses the department office, offices of members of the staff, classrooms, a graduate study room, a student lounge, and the Engineering Library.

A new *traffic engineering laboratory* for teaching and research is located in Civil Engineering Hall. The laboratory, with a floor area of 1,700 square feet, contains a 20 by 6½ foot traffic signal demonstration panel with 15 different intersections which can be operated individually or collectively with all types of traffic signal controllers. The laboratory is also equipped to demonstrate traffic sign preparation. Radar speedmeters, recording and non-recording traffic counters, a twenty-pen recorder, parking meters, and traffic paint striper are also available in the laboratory.

Talbot Laboratory. The Talbot Laboratory is the outstanding building of its kind in the country. Its floor area of 82,000 square feet is shared by the Department of Civil Engineering and the Department of Theoretical and Applied Mechanics. It houses the following laboratories for testing, research, and instruction.

The *structural laboratory* is in the large central crane bay, where testing machines varying in capacity from 30,000 pounds to 3,000,000 pounds are located. The latter machine has a vertical height sufficient to accommodate tension and compression specimens thirty-eight feet long. Large machines for determining the fatigue strength of full-size structural members and the strength of members subjected to rapidly applied loads are important features of this laboratory. The laboratory is served by a traveling crane. Extensive facilities are available for studying the behavior of structures and structural components of wood, steel and other metals, reinforced concrete, and prestressed concrete and for the study of vibrations in structures and their action under impact loads, earthquake motions, or blast forces.

The *concrete laboratory* is equipped for the study of the physical properties of concrete as influenced by proportioning, mixing, placing, and curing.

The *highway materials laboratories* are equipped for tests and research in bituminous materials and mixes, as well as in stabilized soils, soil-aggregate mixtures, and other nonbituminous highway materials. The *soil laboratories* are equipped to perform the various soil tests and provide excellent facilities for research, including a vertical reflecting projector for compilation of maps from aerial photographs and other sources.

Graduate students in civil engineering often elect courses which make use of the laboratories of the Department of Theoretical and Applied Mechanics which are also located in this building. The laboratories include the *hydraulics laboratory*, which is equipped with a standpipe, pumps, weirs, orifice tanks, turbines, long concrete channels, and other facilities for instruction and research in hydraulics; the *applied mechanics laboratory,* equipped with standard and special testing machines of various types and capacities; the *fatigue of metals laboratory,* equipped with a variety of machines for testing metals under fatigue loading; the *concrete research laboratory,* which is well equipped with testing machines, mixers, a concrete saw, a core drill, and other tools and equipment used in fabricating and testing members of plain and reinforced concrete and which is supplemented by the large crane bay and its testing machines; and several special laboratories, such as those for plastics, photoelastic investigations, and creep of metals.

Two well-equipped machine shops are provided for use in making and repairing equipment and apparatus for instruction and research.

Sanitary Engineering Laboratory. A separate three-story brick building provides classrooms, offices, and laboratories for instruction and research in sanitary engineering. A wide variety of precision instruments is available for the physical, biological, radiological, and chemical, including biochemical, investigation of water, sewage, and industrial wastes. The laboratory has pilot plants for the treatment of water and wastes with space and shop facilities available for the construction of additional apparatus and special equipment. In addition, there is a complete sewage treatment plant at the University Airport available for experimental purposes.

Research in the purification of water, in the treatment of sewage and of industrial wastes, and in other aspects of sanitary engineering requiring hydraulic, chemical, and biological equipment is being carried on in the Sanitary Engineering Laboratory. Opportunities to participate in the established projects and to pursue research independently on selected projects are offered.

Surveying Building. This building is situated on the south campus. It contains a photogrammetric laboratory, drafting rooms, classrooms, offices, and an extensive collection of modern instruments which are used for advanced instruction in geodetic and photogrammetric engineering. For instruction in precise control surveying including geodetic astronomy, the

26

following equipment is available: first-order Wild N-3 level, Wild T-2 theodolite with prismatic astrolable attachment, Zeiss pendulum level, lovar tapes, precise foot and yard rods, chronometer, etc. For advanced instruction and research in photogrammetry the following are available. Nistri Photocartograph V, Zeiss SEG IV and SEG II rectifiers, Zeiss stereotope, stereocomparagraphs, contour finders, sketchmasters, slotted templet cutter, stereoscopes, reflecting projector, etc.

Hydraulic Engineering Laboratory. The Hydraulic Engineering Laboratory occupies a total usable space in excess of 10,000 square feet. Over 60 per cent of the area is used for the construction and testing of hydraulic models and flow apparatus. The remainder of the area is devoted to offices, shop facilities, and darkroom. The main laboratory pumping system is composed of five pumps with a combined capacity of 5,000 gallons per minute at a head of about forty-five feet. Water storage and sump facilities, with a capacity in excess of 22,000 gallons, supply the water recirculation

TEST TO FAILURE OF A TWO-SPAN CONTINUOUS PRESTRESSED CONCRETE BEAM. The test is being conducted in the structural laboratory as part of an investigation of prestressed concrete for highway bridges aimed at the development of general design criteria for the safe and economical use of prestressed concrete in high bridges.
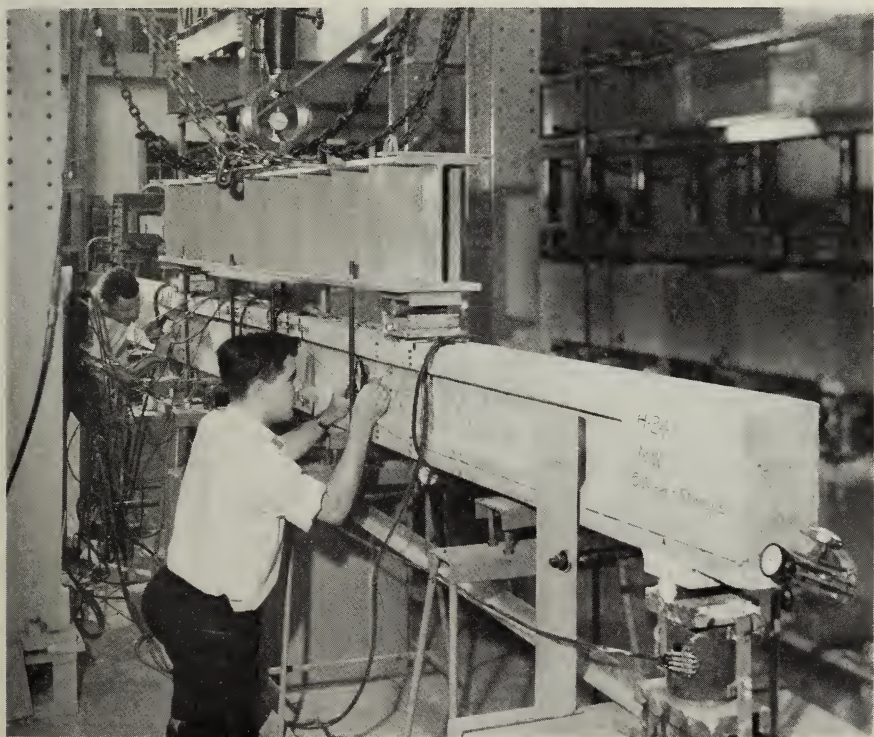
system. Piping arrangements are designed to permit simultaneous constant head and high rate flows without interference.

A separate system for the use of graduate students is maintained in the north laboratory. This test area contains its own pump, water supply, circulation system, and measuring apparatus.

Instrumentation is of the latest types. A unique feature of the laboratory is a heated space 10 feet wide and 330 feet long equipped with a traveling crane for the handling of heavy equipment. This space is well adapted to studies relating to either open channel or pipe flow.

Available within the laboratory are complete shop facilities for the construction of research installations and models, including apparatus for molding plastic materials.

Cameras for both still and moving pictures are a part of the regular equipment. A darkroom permits the processing of photographs. Mechanical calculators are available for the analytical interpretation of experimental data.

Test Track Building. This building, with a floor area of 2,400 square feet, houses a circular test track used for the testing of highway pavement materials. Repetitive wheel loads, approximately 200,000 a week, can be applied to six sections of pavement placed in a circular area of twenty-five feet outside diameter and nine feet inside diameter. The pavement materials are placed on at least three feet of a subgrade soil. The wheel loads can be oscillated over a thirty-inch width of the pavement surface.

The test track can be used to compare pavement performance of different materials and to study the basic behavior of highway pavements. The laboratory is equipped with an overhead crane and aggregate bins for handling the large quantities of materials used in the testing. Supplementary laboratory equipment is also available to perform various soil tests.

Library Facilities. The University Library's resources for advanced study and research are outstanding. The present holdings are in excess of three million volumes, with all but about two hundred thousand volumes located in Urbana. More than fifteen thousand periodicals and twenty-five thousand serial publications are currently received, extensive back files are maintained, and the Library is a government document and Atomic Energy Commission depository.

The Library's bibliographical facilities include a union catalog representing titles owned by about two dozen major American and foreign libraries, printed catalogs of the book collection in the Library of Congress and several other national libraries, national and trade bibliographies of special subjects, and similar aids.

Outstanding collections have been developed in the science-technology fields. The Engineering, Physics, Mathematics, Chemistry, and Geology

libraries are conveniently located to the College of Engineering. Their combined collections include over twenty-two hundred journal titles and one hundred fifty-five thousand books. Graduate students have free access to all library bookstacks. Micro-reproduction facilities, interlibrary loan service from other institutions for those engaged in research for dissertations, individual reference service, and assistance in using the collections, catalogs, and indexes are also available.

Computational Aids. Available for civil engineering research are a number of computational aids for use in studies of numerical methods of various kinds and for the numerical solution of problems of stress analysis, instability, vibration, impact, heat flow, etc. Electric desk calculators are located in computing laboratories in Talbot Laboratory, Civil Engineering Hall, and the Structural Engineering Annexes. Use may be made of the IBM punched card tabulating and computing equipment in the Statistical Service Unit.

Use may also be made of the Illiac, the high-speed electronic digital computer designed and built by the University. This computer is one of the best of its type in the country, having a high-speed memory of 1,024 numbers of forty binary digits (twelve decimal digits) and a magnetic drum memory of 12,800 numbers. When operating with the high-speed memory, the computer can multiply approximately 1,200 pairs of numbers per second. Among the general programs available are those for the solution of sets of simultaneous linear algebraic equations, the integration of linear or nonlinear differential equations, or of a set of differential equations, the evaluation of the roots of high order polynomials, and the determination of the eigenvalues and the eigenvectors of matrices. Using only the high-speed memory, a system of thirty-nine simultaneous linear algebraic equations with thirty-nine unknowns can be solved in less than four minutes. With the magnetic drum memory, it is possible to solve a system of 140 simultaneous equations in approximately two hours. Use may also be made of the IBM 650 computer. This computer is equipped with index registers, floating point equipment, and three magnetic tape units. It can be used for a variety of statistical and engineering computations.

Special purpose programs developed by civil engineering staff or graduate students are available for both computers for the static and dynamic analysis and design of a variety of complex structures, for traffic and construction equipment allocation studies, for the reduction of test data, and for many other problems in research. Both computers are used extensively in the analytical research programs in civil engineering. They make possible investigations involving complex computations which are impracticable or even impossible by other means and greatly expand the scope of analytical research.

Courses in Civil Engineering and Sanitary Engineering

The prerequisite for graduate work in civil engineering and sanitary engineering is the equivalent of the undergraduate courses required for the degree of Bachelor of Science in the branch of the subject in which registration is desired.

In the following statements concerning courses, the designation I indicates the course is offered the first semester; II indicates it is offered the second semester; and I, II indicates it is offered both semesters.

Use of the designation I or II in the title of a course does not necessarily indicate the course is given only in the first or second semester.

Courses for Graduates

401. Geodetic Engineering. Elements of geodesy; principles and practice of precise triangulation, traverse, and levels. I; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering. SCHMIDT.

402. Geodetic Engineering. Precise astronomic determination of time, latitude, longitude, and azimuth. II; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering. SCHMIDT.

403. Photogrammetry. Study of the principles of stereoscopy and geometrical optics; aerial cameras, their design and calibration; the design, construction, and operation of stereoscopic plotting machines; mathematics of stereoscopic orientation and model deformation. I; 1 unit. Prerequisite: Civil Engineering 302, or consent of instructor. KARARA.

404. Photogrammetry. Theory of errors of stereoscopic photogrammetry; aerotriangulation (spatial and radial), its theory and applications to various civil engineering problems; electronics in photogrammetry; practice in compiling maps from aerial and terrestrial photographs. II; 1 unit. Prerequisite: Civil Engineering 302, or consent of instructor. KARARA.

420. Pavement Design, I. Analysis and methods of measurement of road surface properties related to vehicle performance; factors affecting pavement durability; traffic wear, climate, chemical action, combined effects; composition design of flexible and rigid pavements for proper surface properties, load carrying capacity, wear resistance, stability and durability. I; 1 unit. Prerequisite: Civil Engineering 220 or equivalent. DANNER.

421. Pavement Design, II. Structural design of flexible and rigid pavements; loading characteristics, static, impact and repeated loads; load distribution through pavement layers, factors affecting distribution, methods of analysis; evaluation of subgrade support; criteria for selecting design values. II; 1 unit. Prerequisite: Civil Engineering 220 or equivalent. DANNER.

426. Traffic Planning. Traffic Engineering planning functions; urban and rural master traffic plans; traffic analyses for new or existing streets, highways, and terminal facilities. I; 1 unit. Prerequisite: Civil Engineering 325 or equivalent. BAERWALD.

427. Geometric Highway Design. Highway classification; highway capacity; highway design controls; sight distance; horizontal and vertical alignment; cross section elements; highway types; controlled access highways; design of at-grade

intersections, grade separations, and interchanges. II; 1 unit. Prerequisite: Civil Engineering 325 and 426, or consent of instructor. BAERWALD.

428. **Traffic Engineering Operations.** Theory of traffic control; laws and ordinances; design and application of traffic control devices; special street designations; parking design and control; street illumination; miscellaneous traffic control designs. II; 1 unit. Prerequisite: Civil Engineering 325 and 426, or equivalent. BAERWALD.

435. **Railway Construction and Maintenance.** Roadbed load capacity; economic design of track; advanced geometric design; economics of maintenance; grade crossing separation; review of specific projects. I; 1 unit. Prerequisite: Civil Engineering 335. HAY.

436. **Railroad Location and Operation.** Traffic and traffic capacity; optimum train size, performance, and scheduling; validity and accuracy of current

TRIAXIAL COMPRESSION MACHINE FOR TESTING SOILS. This triaxial compression testing machine is being used in a study of illite to determine the influence on the shearing strength and consolidation characteristics of different exchangeable ions, including calcium, magnesium, hydrogen, sodium, and ammonium. Illite is one of the three clay minerals and is found in the glacial deposits of North America.
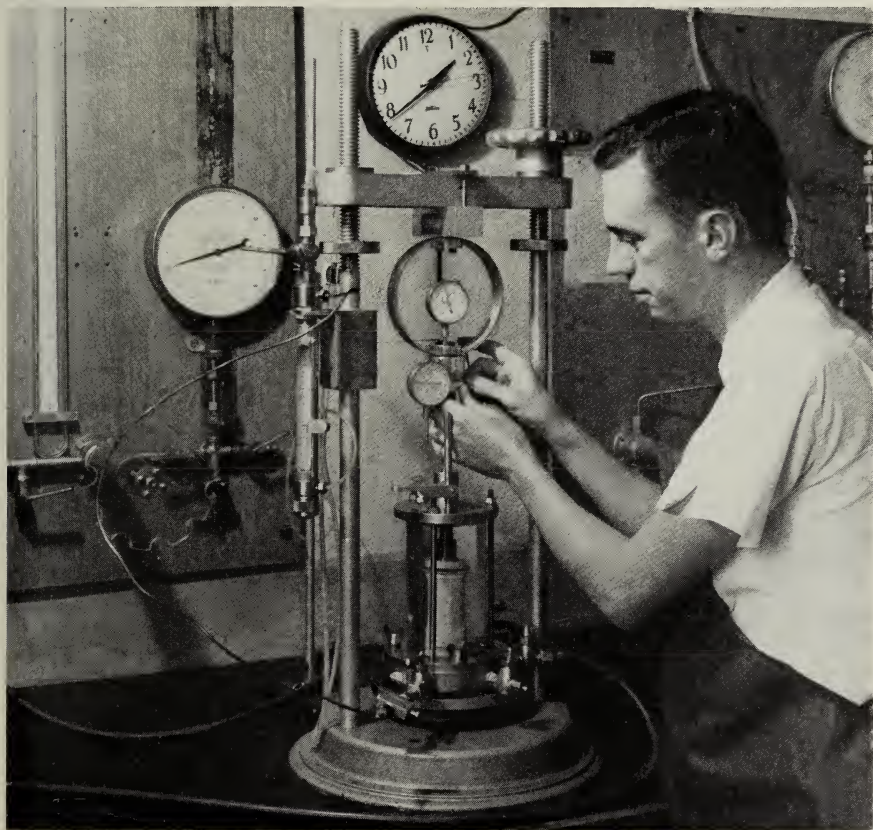
practices; regional operating factor; optimum size of plant and modern location. II; 1 unit. Prerequisite: Civil Engineering 336, or consent of instructor. HAY.

440. **Theory of Water Treatment.** Properties of water and criteria of water quality; gas transfer operations in water treatment; chemical treatment processes; corrosion and corrosion contol; sedimentation; filtration; disinfection; control of aquatic growths; and control of tastes and odors. I; 1 unit. Prerequisite: Chemistry 122; Microbiology 101. ENGELBRECHT, EWING.

441. **Water Purification Laboratory and Design.** An extension of principles and application to experimental determination of design and operational criteria for various physical, chemical, and biological unit operations used in water purification processes. I; 1 unit. Prerequisite: Credit or registration in Civil Engineering 440 or consent of instructor. GAUDY.

442. **Theory of Waste-Water Treatment.** Composition, properties, and analysis of wastes; microbiology of waste treatment; pollution of natural waters; sedimentation; chemical treatment; aerobic and anaerobic treatment processes; disposal of waste sludges. II; 1 unit. Prerequisite: Chemistry 122; Microbiology 101. ENGELBRECHT.

443. **Waste Treatment Laboratory and Design.** An extension and application to experimental determination of design and operational criteria for various physical, chemical, and biological unit operations used in waste treatment processes. II; 1 unit. Prerequisite: Credit or registration in Civil Engineering 442. GAUDY.

444. **Industrial Wastes.** Advanced considerations of industrial wastes problems of major waste-producing industries including the process producing the waste, waste composition, treatment methods, and inplant abatement techniques. II; ½ to 1 unit. Prerequisite: Civil Engineering 442 and 443 or consent of instructor. GAUDY.

445. **Fundamentals of Biological Treatment.** A detailed consideration of basic biological and chemical phenomena applied to aerobic and anaerobic treatment of aqueous wastes. I; 1 unit. Prerequisite: Credit or registration in Civil Engineering 443 or consent of instructor. ENGELBRECHT, GAUDY.

446. **Design of Water and Waste Treatment Plants.** A study of the fundamental factors affecting choice of treatment units and combination of unit processes into an integrated plant. II; 1 unit. Prerequisite: Civil Engineering 440, credit or registration in Civil Engineering 442, or consent of instructor. EWING.

447. **Radioactive Waste Disposal.** Sources and characteristics of radioactive wastes; methods of treatment; ultimate disposal; fate of radioisotopes in the environment; permissible levels in air and water; current levels in water supplies; water treatment methods; monitoring techniques; solid waste disposal; gaseous waste disposal; air monitoring; and reactor site selection and hazards evaluation. II; ½ to 1 unit. Prerequisite: Physics 282 or Chemistry 398 (Nuclear Engineering 398) or consent of instructor. EWING.

450. **Advanced Hydrologic Analysis and Design.** Hydrologic cycle; hydrometeorology; collection of data; hyetograph and hydrograph analyses; infiltration and evapotranspiration studies; ground water exploration and recharge; statistical analyses; determination of waterway areas; flood routings; river and

reservoir regulations; design and planning of flood control projects; and modern development such as radar weather; radioactive tracers; disposal of nuclear wastes, and electronic analogs. I; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering, or consent of instructor. CHOW.

452. Water Resources Planning and Development. Purposes and techniques of planning water resources developments; evaluation of social and economic aspects of water control projects and development of an actual proposal. I; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering or consent of instructor. GUILLOU.

455. Water Power Engineering. Survey and evaluation of power resources; preliminary investigation of plant site; hydrologic analysis of power supply; study and selection of hydraulic turbomachinery; design of hydraulic structures, power plant and appurtenances, and control works; cavitation; water hammer analysis; governor design; power economics; design and analysis of hydro, steam, and nuclear power associations. II; 1 unit. Prerequisite: Consent of instructor. CHOW.

456. Hydraulics of Surface Drainage. Applications of hydraulic and hydrologic principles; elements of channel design, hydrologic determination of design flow, hydraulics of culverts and bridge openings, overland flow, flow in gutters and inlets, and hydrologic and hydraulic design of a bridge opening or culvert system. II; 1 unit. Prerequisite: Theoretical and Applied Mechanics 232 and 234, or equivalent. GUILLOU.

458. Open Channel Hydraulics. Basic hydromechanics; flow types; channel characteristics; flow-profile computations; hydraulic jump analysis; design of nonerodible, erodible, and grassed channels and transitional structures; study of supercritical flow and unsteady flow; modern developments in theory and design practice; application of numerical method, method of characteristics, method of singular point, and electronic digital computers and analogs. II; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering, or consent of instructor. CHOW.

460. Structural Analysis. Basic theory of indeterminate structures; deflections and displacements; continuous beams and frames; virtual work; qualitative and quantitative influence lines. I, II; ½ to 1 unit. Prerequisite: Bachelor of Science degree in engineering with a course in theory of simple structures. OLIVER.

461. Structural Theory and Design. Advanced structural theory from the standpoint of design, analysis, and behavior, with particular emphasis on analysis; evaluation of methods of elastic analysis of structures; limit design and analysis; continuous beams and frames; multiple-story structures; space frames; arches. I, II; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering; Civil Engineering 361 or 460, or equivalent. HALL.

462. Structural Theory and Design. Statically indeterminate trusses; continuous trusses; steel arches; secondary stresses; suspension bridges; long-span roofs. I, II; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering; Civil Engineering 361 or 460, or equivalent. MOSBORG.

464. Reinforced Concrete Design. Theories of action of beams, slabs, and columns of reinforced concrete; codes and specifications and their influence on design; effect of continuity. I, II; 1 unit. Prerequisite: Bachelor of Science degree in engineering with undergraduate courses in structures. BRISCOE.

465. **Structural Design in Metals.** Theories of behavior of structural metal members and their components; interpretation of codes and specifications for the design of bridges and buildings. This course and Civil Engineering 475 supplement one another in the study of theoretical and experimental behavior of metal structures. I, II; 1 unit. Prerequisite: Bachelor of Science degree in engineering with courses in structures. GAYLORD.

467. **Behavior of Reinforced Concrete Structures.** Ultimate strength and behavior of statically indeterminate reinforced concrete structures; applicability of elastic analysis to framed structures; analysis and design of floor slabs in buildings. II; 1 unit. Prerequisite: Civil Engineering 366. SIESS.

468. **Analysis and Design of Prestressed Concrete Structures.** The principles of linear prestressing; the properties of materials used in prestressed concrete; service load and ultimate design of simply supported prestressed concrete beams; strength and behavior of prestressed concrete beams; composite sections; analysis, behavior and design of continuous prestressed concrete beams. I, II; 1 unit. Prerequisite: Bachelor of Science degree in civil or architectural engineering with courses in reinforced concrete and in analysis of indeterminate structures. KHACHATURIAN.

469. **Wood Structures.** Theory and practice in the design of modern wood structures; the effect of the plant origin and physical structure of wood on its mechanical strength; fasteners and their significance in design and the development of design formulae. I, II; 1 unit. Prerequisite: Bachelor of Science degree in civil, architectural, or agricultural engineering, or consent of instructor. OLIVER.

471. **Numerical and Approximate Methods of Structural Analysis.** Methods of successive approximations and numerical procedures for the solution of complex problems with applications to bridges, buildings, and aircraft structures: influence lines, moments and deflections of beams with axial load, buckling strength of columns, moments and deflections of beams resting on elastic or plastic supports, vibration of beams, analysis of arches, moments and deflections of plates, and other problems. I, II; 1 to 2 units. ROBINSON.

472. **Advanced Numerical Methods in Engineering.** Basic concepts in numerical and approximate methods: successive approximations, relaxation, finite differences, ordinary boundary value problems, initial value problems, partial differential equations, characteristic value problems, methods of interpolation, variational procedures. Special study of selected topics including vibrations of complex structures, blast, impact, and earthquake effects on structures, buckling and flexure of frameworks, torsion of solid and thin-walled sections, lateral buckling of beams, bending and buckling of plates and of stiffened plates, plane stress and axially symmetric problems in elasticity, and other topics. II; 1 to 2 units. Prerequisite: Civil Engineering 471. ROBINSON, SUTCLIFFE.

473. **Analysis and Design of Plates and Shells.** Fundamental theories of bending and buckling of plates; practical application of theories in analysis and design of reinforced concrete bridge and building floors, highway and airport pavements, and structural plate components in metal; theory of shells with application to tanks, pressure vessels, shell roofs and hipped plate construction. I; 1 to 2 units. Prerequisite: Consent of instructor. VELETSOS.

474. **Behavior of Structures Under Dynamic Loads.** Free vibrations, forced vi-

bration, and transient response of structures and structural components having one or many degrees of freedom; analytical methods for the effects of wind load, explosion blast, impact, earth tremors, and other time dependent excitations; effects of damping and inelastic action; propagation of stress waves; wind induced vibrations with application to cables, pipelines, and tall stacks. II; 1 to 2 units. Prerequisite: Consent of instructor. VELETSOS.

475. **Behavior of Steel Structures.** A critical evaluation of the actual behavior of metals, connections, members, and structures; the significance of this behavior in terms of design and the development of design specifications. This course and Civil Engineering 465 supplement one another in the study of theoretical and experimental behavior of metal structures. I; 1 unit. Prerequisite: Graduate standing in civil engineering or theoretical and applied mechanics. MUNSE.

476. **Design of Lightweight Structures.** Fundamental theory of thin-walled structural members; applications to design of metal structures with emphasis on light-gage, cold-formed members; comparative studies of design specifications for metal structures. II; 1 unit. Prerequisite: Civil Engineering 465. GAYLORD.

477. **Design of Structures for Dynamic Loads.** Nature of dynamic loading from earthquakes and bomb blasts; nature of dynamic resistance of structural elements and complete structures; concepts of limit design; review of methods of analysis; significance and interpretation of results of analyses; criteria for

TWO-HUNDRED-THOUSAND-POUND FATIGUE TESTING MACHINES. Three machines, designed and built by the University, apply 180 cycles of load per minute, so that in one or two weeks fifty years of life of a bridge member can be simulated. Riveted, bolted, or welded connections, and beams can be tested. A four-bolt specimen is shown at the left in this view.
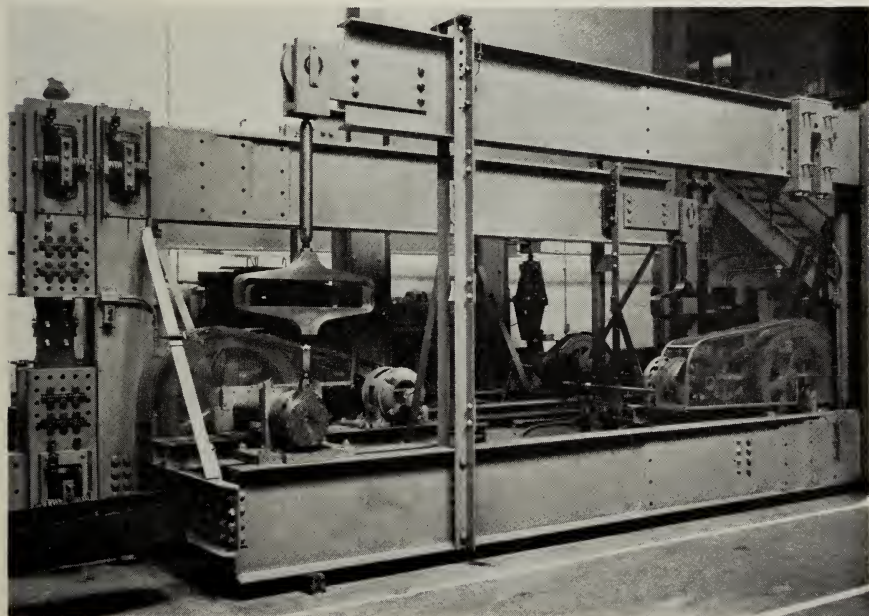
design of blast resistant structures; criteria for design of earthquake resistant structures; application to actual problems. I; 1 unit. HALTIWANGER, NEWMARK.

480. Earth Pressures and Retaining Structures. Classical and modern pressure theories and their experimental justification; pressures and bases for design of retaining walls, bracing of open cuts, anchored bulkheads, cofferdams, tunnels and culverts. I; 1 unit. Prerequisite: Credit or registration in Civil Engineering 383, or consent of instructor. DEERE, PECK.

481. Earth Dams and Related Problems. Fundamentals of problems of slope stability; seepage in composite sections and anisotropic materials; methods of stability analysis; mechanism of failure of natural and artificial slopes; compaction; field observations. II; 1 unit. Prerequisite: Credit or registration in Civil Engineering 384, or consent of instructor. DEERE, PECK.

482. Measurement of Soil Properties. Laboratory and field work in soil sampling, classification, and testing; experimental studies of modern soil mechanics parameters and theories with emphasis on applications to design problems. Experiments include permeability, consolidation, direct shear, and triaxial shear. The research approach is used to point out interpretations and limitations of data in practice. I, II; 1 unit. Prerequisite: Credit or registration in Civil Engineering 383.

483. Soil Mechanics. Advanced studies of research techniques in soil mechanics and foundation engineering. I; 1 unit. Prerequisite: Civil Engineering 384 or consent of instructor. PECK.

484. Foundation Engineering. Critical study of case histories of projects in foundation engineering; current procedure for design and construction of foundations, embankments, and waterfront structures. II; 1 unit. Prerequisite: Credit or registration in Civil Engineering 384 or consent of instructor. DEERE, PECK.

485. Soil Engineering for Transportation Facilities. Problems of soil classification; factors affecting the stability or subgrades, slopes, and embankments. II; 1 unit. Prerequisite: Civil Engineering 383 or equivalent. THORNBURN.

494. Municipal Administration and Engineering. Legal authority of municipalities, forms of municipal government; municipal functions, organization, and management; city finance; engineering functions of city government; city planning and zoning; building codes and inspection; street lighting; public utilities; city cleaning; recreational development. II; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering or consent of instructor. DANNER.

495. Highway and Traffic Seminar. Presentation and discussion of current problems and research developments in highway transportation, administration, and engineering. Should be followed by Civil Engineering 496. I; no credit. BAERWALD, DANNER.

496. Highway and Traffic Seminar. Continuation of Civil Engineering 495. Presentation and discussion of current problems and research developments in highway transportation, administration, and engineering. II; no credit. BAERWALD, DANNER.

497. Special Problems. Individual investigations or studies of any phase of civil engineering selected by the student and approved by his adviser and the staff

member who will supervise the investigation. I, II; 0 to 4 units. Prerequisite: Consent of instructor.

499. Thesis Research. I, II; 0 to 4 units.

Suggested Topics for Civil Engineering 497

A sufficient number of regular courses have been established to cover adequately some phases of civil engineering. Even in these, students may wish to take advantage of Civil Engineering 497 for special studies. In other phases, extensive use is made of Civil Engineering 497 to cover subjects not now included in the regular courses. The following topics are suggested, but registration is not restricted to these topics.

HIGHWAY AND TRAFFIC ENGINEERING

Highway Transportation. Functions of transportation in the economic system; types of transportation, characteristics and uses of each type; development of highway transportation; elements of highway transportation, their organization and functions; regulation of transportation.

Highway Organization and Administration. Highway agencies and their division of responsibilities; principles of administrative organization; forms of highway administrative bodies and legislative control; analysis of highway agency functions and organizational development; personnel management; public relations.

Highway Economics and Finance. Composition of highway transportation costs; analysis of highway costs and costs of vehicle operation; sources of highway funds, taxation, bonds, toll roads; highway benefits and basis for distribution of highway costs; allocation of funds to highway agencies.

Highway Laws and Regulations. Street, highway, and traffic department legal rights and responsibilities; intergovernmental relations; right-of-way control and freeway laws; traffic laws and ordinances; driver licensing; vehicle inspection; development of uniform laws and ordinances.

Traffic Records and Accident Analyses. Types of traffic record systems; design of record forms; annual inventory of traffic safety activities; analysis of traffic accidents, vehicular and pedestrian; engineering factors in accidents; non-engineering records of value to the traffic engineer; coordination of engineering education and enforcement.

Highway Planning and Programming. Legal authority for highway and street development; political significance of highway and street systems; responsibility and interrelationships of highway agencies; classification of highways; determination of highway costs and allocation of funds; determination of highway needs; improvement priority ratings; right-of-way determination; and roadside regulation and access control.

History and Development of Highways

Highway Materials

Roadway Location and Design

Highway Maintenance and Operation

Analyses of Traffic Problems

HYDRAULIC ENGINEERING

Engineering Hydraulics. Extension of fundamentals of basic fluid mechanics for hydraulic research and applications.

Ground Water. Special studies of hydrogeology, geophysical exploration, hydrodynamics of flow through porous media, and ground water hydrology and development.

Erosion and Sedimentation. Investigation of land erosion, river and reservoir sedimentation, sediment transport, density current, and advanced fluvial hydraulics.

Hydrometeorology. Study of atmospheric sciences including meteorology, radar weather, artificial rain-making, and hurricane and tornado analyses for the design of structures.

Drainage and Flood Control. Application of hydraulic and hydrologic principles and methods to land drainage problems and flood-control procedures and designs.

Irrigation. Planning of irrigation projects and design of irrigation structures.

Coastal Engineering. Study of waves, oceanography, and movement of sediments along coastal areas for the design of coastal structures and harbor facilities.

Dam and Reservoir Design. Analysis, design, and construction of gravity and earth dams and their appurtenances and various types of reservoirs.

Operations Research in Water Resources Planning and Development. Application of operations research and system engineering to the complex function of water resources planning and development, including concept of prototype system, mathematical model of programming for digital computers, synthetic hydrology, queueing theory, and Monte Carlo method.

RAILWAY ENGINEERING

Grade Crossing Protection and Separation

Economics of Train Make-up and Operation

Rail Design and Defects

Track Under Load

GENERAL TRANSPORTATION

Transportation Planning. Application of appropriate transportation design principles and media to various transportation needs; coordination and integration; organization; financial aspects; roles of labor and of government; case studies and problems.

New and Minor Transport Media

Selected Transportation Problems

Waterways

Airways

Pipelines

Urban Transit Design

Stream Pollution. The chemical, biological, and hydrological factors in determining quality of water in rivers, lakes, and streams; stream surveys; water quality criteria; administration of stream pollution control.

Water Quality. Impurities in surface and ground waters; their source; effect of impurities on the various beneficial uses of water; effect of surface and ground water flow upon the nature and concentration of the impurities.

Industrial Wastes. Characterization of industrial wastes; special analytical methods; water pollution and water quality criteria as applied to industrial wastes; waste abatement and pretreatment; special treatment processes and operations; joint treatment.

Biological Aspects. Design criteria, special analytical methods; toxicity; biological assay techniques; operational parameters.

Air Pollution

Industrial Hygiene

Radiological Health

Refuse Collection and Disposal

Courses for Graduates and Advanced Undergraduates

301. **Advanced Surveying.** Precise horizontal and vertical control surveys; state plane coordinate systems, and special construction surveys. II; ½ unit. Prerequisite: Civil Engineering 207 (Summer Surveying Camp), senior standing, or consent of instructor. SCHMIDT.

302. **Photogrammetric Engineering.** A study of metrical photography in civil engineering practice; characteristics and interpretation of aerial and terrestrial photographs; stereoscopic compilation of maps from photographs; mosaics; economics of photogrammetry; map reproduction. I, II; ½ unit. Prerequisite: Civil Engineering 207 (Summer Surveying Camp), senior standing, or consent of instructor. KARARA.

303. **Cadastral Engineering.** Original, retracement, and subdivisional surveys in relation to real property. I; ½ to 1 unit. Prerequisite: Civil Engineering 207 (Summer Surveying Camp), senior standing, or consent of instructor. ELDRIDGE, SCHMIDT.

304. **Survey Adjustments and Least Squares.** Theory of errors; method of least squares; measures of precision; the adjustment of triangulation, traverse and level nets; and special problems. II; ½ to 1 unit. Prerequisite: Civil Engineering 207 (Summer Surveying Camp), senior standing, or consent of instructor. KARARA.

315. **Construction Productivity.** Introduction to the application of scientific principles to the measurement of and the forecasting of productivity in construction engineering; conceptual and mathematical formulations of the labor, equipment, and material factors affecting productivity. I, II; ½ unit. Prerequisite: Civil Engineering 215, credit or registration in Mathematics 263 or equivalent, or consent of instructor.

316. **Construction Planning.** Introduction to the application of scientific principles to the normative planning of construction operations. I, II; ½ unit. Prerequisite: Civil Engineering 315 or consent of instructor.

318. **Construction Cost Analyses and Estimates.** Introduction to the application of scientific principles to costs and estimates of costs in construction engineering; concepts of and statistical measurements of the factors involved in direct costs, general overhead costs, cost mark-ups and profits; the fundamentals of cost recording for construction cost accounts and cost controls. I, II; ½ unit. Prerequisite: Civil Engineering 315 or consent of instructor.

321. **Bituminous Materials and Mix Design.** Properties and control testing of bituminous materials; analysis of bituminous paving mixtures; composition and design of asphaltic concrete and soil-asphalt mixes. I, II; ½ unit. Prerequisite: Civil Engineering 214 and 220, or consent of instructor. HERRIN.

322. **Development of Highway Facilities.** Analysis of factors in developing a highway transportation facility; traffic estimates and assignment; problems of highway geometrics and design standards; planning and location principles; intersection design factors; street systems and terminal facilities; programming improvements; drainage design; structural design of surface; concepts of highway management and finance; highway maintenance planning. I, II; 1 unit. Prerequisite: Civil Engineering 220 or consent of instructor.

325. **Highway Traffic Characteristics.** Vehicle operating characteristics; driver characteristics; pedestrian characteristics; roadway characteristics as they individually, and collectively as traffic stream characteristics, are related to the planning, design, and operation of highway facilities. I, II; ½ unit. Prerequisite: Civil Engineering 220 or consent of instructor. BAERWALD.

333. **Urban and Regional Transportation.** Importance of transportation and its relation to urban and regional planning; characteristics of transport systems; transportation planning including surveys, data analysis, and problems of administration and finance; coordination and integration of transport. I; ½ to 1 unit. Prerequisite: Senior or graduate standing, or consent of instructor. HAY.

334. **Airport Design.** Basic principles of site selection for airports and fundamental considerations of design, construction, and maintenance of airport pavements and structures. II; ½ to 1 unit. Prerequisite: Civil Engineering 220 and senior standing in civil engineering, or consent of instructor. HERRIN.

335. **Railway Construction and Maintenance.** Loads and load distribution on track and subgrade; roadbed construction and stabilization; track stresses, design, and materials; turnouts and crossings; maintenance programs. I; ½ to 1 unit. Prerequisite: Senior standing or consent of instructor. For those taking a minor in railroad or transportation engineering, Civil Engineering 230 is required. It may be taken concurrently. HAY.

336. **Railway Location and Operation.** Influence of traffic, alignment, distance, gradients, and motive power upon operating expenses; mechanics of train operation; economic design of location. II; ½ to 1 unit. Prerequisite: Senior standing or consent of instructor. For those taking a minor in railroad or transportation engineering, Civil Engineering 230 is required. It may be taken concurrently. HAY.

337. **Signals.** Train movements; systems of signals; track circuits; track capacity; interlockings; economics of signaling. I; ½ to 1 unit. Prerequisite: Senior

standing, or consent of instructor. For those taking a minor in railroad or transportation engineering, Civil Engineering 230 is required. It may be taken concurrently. HAY.

338. Terminals. Design and operation of freight terminal facilities for rail, highway, air and water carriers; passenger terminals; special terminal requirements for specific commodity categories; coordination. II; ½ to 1 unit. Prerequisite: Senior standing, or consent of instructor. For those taking a minor in railroad or transportation engineering, Civil Engineering 230 is required. It may be taken concurrently. HAY.

345. Public Health Engineering. The application of engineering principles to the control of environmental sanitation, including administration, biostatics, communicable disease control, epidemiology, industrial health and air contamination, housing, vector control, radiological health, refuse collection and disposal, milk and food sanitation, swimming pools, and individual water supply and waste water disposal. I; ½ unit. Prerequisite: Senior standing in engineering or consent of instructor. ENGELBRECHT.

348. Air Pollution. A study of the characteristics of air contaminants from industrial and domestic sources; their effect and methods of control; air pollution surveys; and organization of control programs. I; ½ unit. Prerequisite: General Engineering 360 or consent of instructor. ENGELBRECHT.

352. Water Resources. Importance of a water resources program to regional development; evaluation of water resources and a water resource plan, includ-

RESEARCH ON STRENGTH CHARACTERISTICS OF SOIL-AGGREGATE MIXTURES. Equipment for the study of the effect of shape, angularity, and surface texture of aggregate particles on the shear strength of soil-aggregate mixtures is shown. The triaxial compression test, *left*, measures the shear strength, while the newly-developed device, *right*, assesses the angularity of the aggregate particles.
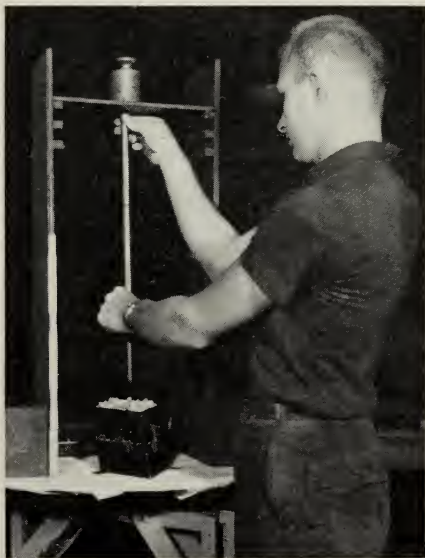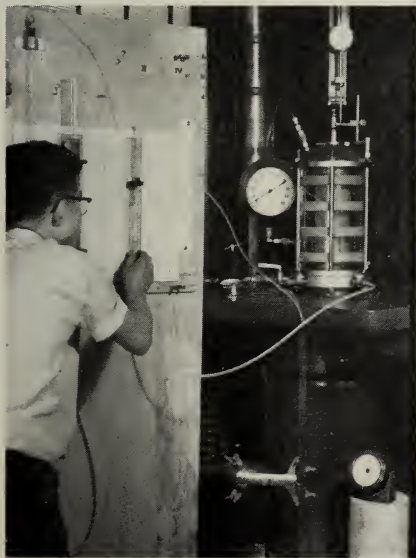
ing constitutional and legislative concepts, as applied to an actual river basin; engineering evaluation of surface, subsurface, and drainage law. I; ¾ to 1 unit. Prerequisite: Credit or registration in Civil Engineering 250. Guillou.

353. **River Hydraulics.** Open channel flow; functions of rivers and streams; stream gaging and analysis; river hydrology; river mechanics; stream sanitation; river navigation; stream control structures. I; ¾ unit. Prerequisite: Theoretical and Applied Mechanics 232. Guillou.

354. **Hydraulic Structures, I.** Functions and types of dams; factors influencing selection of type; seepage, piping and stability investigations for earth dams; outlet works and spillways for low dams; loads, design criteria, and stress investigation procedures for concrete dams. I, II; ¾ unit. Prerequisite: Theoretical and Applied Mechanics 232; credit or registration in Civil Engineering 380. Chow.

355. **Hydraulic Structures, II.** Design of spillways and outlets for high dams, navigation locks and irrigation structures; selection of hydraulic machinery; design of surge tanks, penstocks, and hydroelectric powerhouses; analysis of hydrologic and power market data. II; ¾ unit. Prerequisite: Theoretical and Applied Mechanics 232 and 234. Chow.

356. **Hydraulic Engineering Laboratory.** Fundamental principles; operation and use of model laboratories; dimensional analysis; hydraulic similitude; theory and design of hydraulic models as applied to a specific laboratory problem. II; ¾ unit. Prerequisite: Theoretical and Applied Mechanics 232 and 234. Guillou.

361. **Advanced Structural Analysis.** Continuation of Civil Engineering 262. General theory of continuity; prismatic and nonprismatic members; column analogy; continuous framed structures; trussed structures; numerical methods of analysis. I, II; ½ unit. Prerequisite: Civil Engineering 262. Stallmeyer.

363. **Structural Design in Metals, II.** Continuation of Civil Engineering 263. Members under combined loads; riveted, bolted, and welded connections; simple and moment-resistant connections; ultimate strength and limit design. I, II; ½ unit. Prerequisite: Civil Engineering 263. Dell, Gaylord.

364. **Reinforced Concrete Design, II.** Continuation of Civil Engineering 264. Flexural and torsional deformations of reinforced concrete sections; analysis and design of frames; analysis and design of various types of slabs; elastic and inelastic behavior of reinforced concrete elements; time-dependent effects. I, II; ½ unit. Prerequisite: Civil Engineering 264; credit or registration in Civil Engineering 361. Khachaturian, Siess.

366. **Behavior of Reinforced Concrete Members.** Ultimate strength and behavior of reinforced concrete members and relation between results of research and current specifications for design; members subjected to flexure, axial compression, combined flexure and axial load, combined flexure and shear, and bond. I, II; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering or architecture with courses in structures and reinforced concrete design. Siess, Sozen.

368. **Prestressed Concrete.** Principles of linear prestressing; study of materials used in prestressed concrete; design of simple beams on the bases of ultimate stresses and working loads; design of continuous prestressed concrete beams. I, II; ½ unit. Prerequisite: Civil Engineering 264. Khachaturian.

380. Foundation Engineering. Evaluation of subsoil conditions as they affect the behavior, proportions, and choice of type of foundations; bearing capacity and settlement analyses; character of natural soil deposits; earth pressure theories and retaining wall analysis; slope stability. I, II; 1 unit. Prerequisite: Civil Engineering 210; senior standing.

383. Soil Mechanics. Identification, description, and classification of soils; index properties, weight-volume relationships; hydraulic properties; stress-deformation characteristics; ultimate strength; subsurface exploration; character of natural soil deposits. I, II; ¾ to 1 unit. Prerequisite: Graduate standing or consent of instructor. DEERE, IRELAND.

384. Applied Soil Mechanics. Application of soil mechanics to foundations of buildings; stability of earth slopes; earth pressure and retaining walls; braced cuts; damage due to construction operations. I, II; ¾ to 1 unit. Prerequisite: Civil Engineering 383 or consent of instructor. DEERE, IRELAND.

385. Engineering Aspects of Surficial Soils. Use of geologic and pedologic information and airphoto interpretation techniques in the prediction of engineering properties of soils and the planning of engineering soil surveys. Field trip; estimated expense $5.00. I; 1 unit. Prerequisite: Civil Engineering 210 or consent of instructor. THORNBURN.

391. Numerical and Computer Applications in Civil Engineering. Introduction to digital computers and their programming; development of methods for the efficient use of computers in the solution of design and other problems; description of applications; discussion of role of computers in performing engineering computations. I, II; ½ to 1 unit. Prerequisite: Senior or graduate standing in civil or architectural engineering, or consent of instructor.

Courses in Theoretical and Applied Mechanics

Courses for Graduates

400. Seminar in Engineering Mechanics. There are many special topics in the field of mechanics such as fracture of metals, creep of materials, etc., in mechanics of solids; fluid flow problems such as the nature of turbulence, boundary layer theory, nature and effects of roughness of boundary, effects of free surface; dynamics problems such as vibration of beams with moving loads, the gyroscope, etc. Such special topics as these are covered in this course. Each semester one or more of these topics is selected and announced as the area to be covered in this course during that semester. I, II; ¼ unit. STAFF.

412. Vibration Analysis. Continuation of Theoretical and Applied Mechanics 311. Specific topics are systems of several degrees of freedom; applications of generalized coordinates and Lagrange's equations; boundary value problems in vibration of elastic bodies, including strings, rods, and beams; Stodola's method; iteration process and matrix procedure; vibrations in reciprocating machines, airplane structures and propellers; impact and transient vibrations; self-excited vibration; stability; non-linear systems. II; 1 unit. Prerequisite: Theoretical and Applied Mechanics 311. JONES, STIPPES.

416. Energy Principles in Engineering Mechanics. Designed to introduce the student to the variational principles of mechanics and their applications to engi-

neering problems. The derivation, interpretation, and applications of the principle of virtual displacements, the principle of minimum potential energy, the principle of complementary energy, Castigliano's theorem, Hamilton's principle, and Lagrange's equations of motion constitute the main part of the course. Variational methods of approximation are treated briefly. The material includes numerous illustrative applications to stress analysis of statically determinate and statically indeterminate frames, problems of elastic stability, the theories of rings and curved beams, the theory of elastic plates, vibrations of structures, and wave motions. I; 1 unit. Prerequisite: Mathematics 343 is desirable. LANGHAAR.

421. Mechanics of Materials. Methods of obtaining relations between loads, deformations, stresses and strains in various members. The main topics covered in this course and in Theoretical and Applied Mechanics 422 are curved beams, unsymmetrical bending, thick-walled cylinders, beams on elastic supports, contact stresses, torsion of members with noncircular cross section, stress concentrations, elastic energy methods applied to statically indeterminate members, flat plates, inelastic behavior of various types of members. Introduction to mathematical theory of elasticity; elastic and plastic buckling; criteria of failure by yielding and by fracture. I; ½ to 1 unit. SIDEBOTTOM, SMITH.

422. Mechanics of Materials. Continuation of Theoretical and Applied Mechanics 421. II; ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 421. SIDEBOTTOM, SMITH.

424. Properties of Engineering Materials. Structure of metals and behavior of materials under various conditions of loading and use, including static, creep, fatigue and impact; effects of high and low temperature, strain rate, state of stress, and internal structure; criteria of failure; relation of mechanical properties to behavior; significance of mechanical properties; tests and interpretation of test data; material specifications. II; ½ to 1 unit. CORTEN.

427. Theories of Mechanical Properties and Behavior of Plain Concrete. Theories used in the design of concrete and the factors affecting the properties and behavior of the material and of the test piece. Behavior of plain concrete under different types of environment and of loading, such as long time, repeated, and triaxial are emphasized. The studies involve critical reviews of experimental and analytical investigations. I; ½ to 1 unit. Prerequisite: Bachelor of Science degree in engineering. KELSER.

431. Theory of Ideal Fluid Flow. Together with the following course, topics in advanced fluid mechanics are covered that are the basis of many modern developments. Ideal fluid theory is concerned with an incompressible fluid of negligible viscosity. The differential equations of motion are derived and the several methods of obtaining flow solutions are presented: the obtaining of velocity potentials and stream functions by superposition of the effects of source, doublets, and vortices, and by the methods of conformal mapping. Relations for finding the resultant forces and moments on bodies are derived and applied to bodies such as lifting surfaces. Other topics covered include the theory and application of free streamline flows, vortex motions, and surface wave theory. I; 1 unit. Prerequisite: An elementary course in fluid flow and a course in advanced calculus or equivalent. ROBERTSON.

432. Theory of Flow of Viscous Fluids. Although a logical continuation of

Theoretical and Applied Mechanics 431, this course need not be taken sequentially. Concerned with the theoretical development, analysis, and solution of incompressible viscous fluid flow problems. Starting with the stress relations occurring in viscous fluids, the differential equations of motion are derived and direct and approximate solutions for laminar flows are developed. Boundary-layer theory is presented and the occurrence of turbulence and its characterization introduced. The basic equations for analyzing turbulence flows are introduced and approximate solution for flows in boundary-layers with and without pressure gradients (and separation) pipes and jets are presented. Includes consideration of experimental observation and application to technological problems. II; 1 unit. Prerequisite: An elementary course in fluid flow and a course in differential equations or in advanced calculus. ROBERTSON.

441. **Applied Analysis in Engineering.** A course to provide training in applications of mathematics to engineering problems. Most of the illustrations are taken from engineering mechanics. I; 1 unit. Prerequisite: Mathematics 143; Mathematics 343 and 345 are recommended. LANGHAAR, MILLER.

442. **Applied Analysis in Engineering.** Continuation of Theoretical and Applied Mechanics 441. II; 1 unit. Prerequisite: Mathematics 143; Mathematics 343 and 345 are recommended. LANGHAAR, MILLER.

451. **Theory of Elasticity with Application to Engineering Problems.** A study of the mechanics of elastic deformable bodies, based on the fundamental concepts of equilibrium, geometry of strain, and properties of materials. Relations between stresses, strains, and displacements are studied in detail with special consideration given to their significance in engineering problems. I, II; 1 unit. BORESI, LANGHAAR.

452. **Theory of Elasticity with Application to Engineering Problems.** Continuation of Theoretical and Applied Mechanics 451. II; 1 unit. Prerequisite: Theoretical and Applied Mechanics 451. BORESI, LANGHAAR.

454. **Theory of Shells.** A course designed to provide the theoretical basis of stress analysis of shell-type structures, such as ships, submarines, monocoque aircraft structures, concrete roofs and domes, pressure vessels, and containers for liquids. The material includes the differential geometry of shell theory, equilibrium equations, momentless theory of shells, strains in shells, statically indeterminate problems of shells, energy formulations, and stability of shells. II; 1 unit. Prerequisite: Mathematics 343 or equivalent; Theoretical and Applied Mechanics 451 is desirable but not required; Mathematics 341 or 345 is desirable. LANGHAAR.

461. **Inelastic Behavior of Engineering Materials (Theory of Plasticity).** An outline of a general theory of inelastic behavior involving the relations between loads and stresses and strains in various members that are stressed beyond the elastic range. The cases considered include those in which the inelastic actions involve bodies which are made of materials that behave ideally viscous, ideally plastic, and combinations of the two. Some specific topics are mechanisms of inelastic action of members in which the stresses and strains are essentially uniaxial, such as straight beams, curved beams, and members subjected to combined axial and bending loads; deflection of beams; statically indeterminate members loaded inelastically; inelastic buckling; "shake down" of simple statically indeterminate members; etc. I; ½ to 1 unit. SMITH.

462. **Inelastic Behavior of Engineering Materials (Theory of Plasticity).** The physical and mathematical formulation of the mechanics of inelastically deformed bodies, plastic stress-strain laws, and their association with yield and loading functions. Deals primarily with members subjected to biaxial and triaxial stress conditions. Specific topics include applications to flexure and torsion of prismatic members; expansion of thick-walled cylinders and spherical shells; introduction to problems in plane plastic flow and variational plasticity. II; ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 451 or equivalent. LANGHAAR, SMITH.

464. **Theory of Buckling.** The pertinent information and theoretical background required for the prediction of failure by buckling of structures such as airplanes, ships, bridge trusses, fabricated towers and shells; practical illustrations. Specific topics are elastic columns with various end restraints; buckling of frameworks, arches, rings, and plates; inelastic buckling of columns and plates; lateral buckling of beams; energy theory; Ritz procedure; Euler's equation of the calculus of variations. II; ½ to 1 unit. Prerequisite: Courses in advanced calculus and differential equations are desirable. COSTELLO, LANGHAAR.

493. **Advanced Independent Study (Special Problems).** Individual investigation of studies, either analytical or experimental, in one or more phases of theoretical and applied mechanics, including mechanics of materials, theory of elasticity, theory of plasticity, properties of materials, mechanical vibrations, hydraulics and fluid mechanics, fatigue of metals, etc. I, II; ½ to 2 units. STAFF.

499. **Thesis Research.** I, II; 0 to 4 units. STAFF.

Courses for Graduates and Advanced Undergraduates

311. **Mechanical Vibrations.** Kinematics of vibratory motion; comprehensive study of motion having single degree of freedom; critical speeds of shafts; vibration of systems with several degrees of freedom. Applications to engineering problems. I, II; ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 154, 156, or 211 and 221. JONES.

314. **Advanced Dynamics for Engineers.** Three-dimensional kinematics of a rigid body, general dynamics of a rigid body, moments and products of inertia, kinetic energy, rotation of a rigid body about a fixed axis and about a fixed point, Euler equations of motion, gyroscopic theory; introduction to Lagrange equations; engineering applications. II; 1 unit. Prerequisite: Theoretical and Applied Mechanics 211 or equivalent; Mathematics 341 or 345. BORESI.

321. **Advanced Mechanics of Materials.** Methods used in elementary mechanics of materials are expanded and generalized and used to solve more complex problems. Thick-walled cylinders, torsion of bar having noncircular cross section; curved beams, unsymmetrical bending, flat plates; theories of failure. I, II; ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 221 and 223 or 224. SIDEBOTTOM, SMITH.

323. **Advanced Laboratory in Materials Testing.** Calibration of testing machines and of strain measuring instruments; use of various mechanical and electrical strain gages; interpretation of test results; relation of tests to specifications of materials. I, II; ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 221 and 223. WETEKAMP.

326. **Experimental Stress Analysis.** Measurement of stresses or deformations that are of significance in the engineering design of load-resisting members; use of optical, electrical, and mechanical instrumentation, models, analogies, brittle coatings, electrical resistance gauges, photoelasticity, etc. I, II; ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 150, 211, 221, and 223 or 224. Theoretical and Applied Mechanics 321 is desirable. BOWMAN.

334. **Fluid Mechanics and Advanced Hydraulics.** A study of the basic properties of fluids in general, particularly those that influence the flow of fluids in pipes and open channels, viscosimetry, dimensional analysis, effect of boundary conditions, cavitation, water tunnel, hydraulic jump, water hammer, pumps, turbines. Some laboratory work. II; ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 232 and 234. LANSFORD, MILLER.

346. **Dimensional Analysis and Theory of Models.** The nature and use of dimensions, systematic calculation of dimensionless products, algebraic theory of dimensional analysis, similarity and model laws, and derivation of model laws from differential equations. Applications include von Karman's theory of similarity in turbulent flow, boundary layer theory, topics in open channel flow, model laws for pumps and turbines, topics in structural analysis and vibration theory, topics in the theory of heat. I; ½ to 1 unit. LANGHAAR, WORLEY.

Suggested Courses in Other Departments

Courses for Graduates and Advanced Undergraduates

MATHEMATICS

343. **Advanced Calculus.** I, II; 1 unit. Prerequisite: One year of calculus.

345. **Differential Equations and Orthogonal Functions.** I, II; 1 unit. Prerequisite: One year of calculus.

PHYSICS

383. **Atomic Physics and Quantum Theory for Engineers.** Introduces the student to the basic concepts of quantum theory which underlie modern theories of the properties of materials. Topics covered include elements of atomic and nuclear theory, kinetic and statistical theory, experimental basis of quantum theory, Schrodinger's equation and simple applications, atomic spectra and atomic structure, quantum states of molecules, band theory of solids, and quantum statistics. Lectures and problems. I, II; ¾ to 1 unit. Prerequisite: General physics; general chemistry; Mathematics 345 or equivalent.

Suggested Programs for the Master's Degree

From the courses offered in civil engineering and in other departments, the student may select a variety of programs of study. He is assisted by his adviser in selecting courses which complete his background of fundamental work and which advance his knowledge in one of the fields of specialization in the department.

The following programs are presented only to help the student to evaluate the possibilities of programs in specific fields. Departures from the

suggested programs may be made, in consultation with the adviser, in order to adjust individual programs to the background of the student and to his particular fields of interest. The programs given are for full-time graduate students. Research or teaching assistants normally follow half-time programs and cover the same material as full-time students but at the rate of two and one-half to three units each semester for their two years of study.

Study beyond the degree of Master of Science is an entirely individual matter, and each program is carefully reviewed and selected by the student and his adviser.

HIGHWAY ENGINEERING

First Semester   **Units**

C.E. 321	Bituminous Materials and Mix Design	½
C.E. 322	Development of Highway Facilities	1
C.E. 325	Highway Traffic Characteristics	½
C.E. 385	Engineering Aspects of Surficial Soils	1
C.E. 420	Pavement Design, I	1
C.E. 426	Traffic Planning	1
C.E. 495	Highway and Traffic Seminar	0
		5

Second Semester   **Units**

C.E. 421	Pavement Design, II	1
C.E. 427	Geometric Highway Design	1
C.E. 456	Hydraulics of Surface Drainage	1
C.E. 485	Soil Engineering for Transportation Facilities	1
C.E. 496	Highway and Traffic Seminar	0
		4

Other Courses. Civil Engineering 497, Special Problems (Highway Economics and Finance, one unit, or Highway Organization and Administration, one unit) are suggested alternates for one or more units in the list above.

A student may wish to emphasize some special phase of highway engineering such as drainage, soils, surfaces, materials, traffic, or administration. For this reason, he may wish to substitute other courses in the program which more nearly fit his needs. A full program in traffic engineering is outlined under that heading.

GEODETIC AND PHOTOGRAMMETRIC ENGINEERING

First Semester   **Units**

C.E. 401	Geodetic Engineering	1
C.E. 403	Photogrammetry	1
C.E. 497	Special Problems	½
Geog. 373	Map Compilation and Construction	1
Physics 371	Light	1
		4½

RESEARCH ON REMOVAL OF SYNTHETIC DETERGENTS FROM GROUND WATER. The increased use of synthetic detergents in the home and in industry is resulting in contamination of both surface and ground waters. The mechanisms by which the soil removes these detergents from contaminated ground water are being studied in the Sanitary Engineering Laboratory. The contaminated water containing the detergents, labeled with a radioactive isotope, is passed through sand filters and the radioactivity of the effluent is determined by the proportional counter shown on the right. A hand monitor is used to check for radioactive contamination in the laboratory.
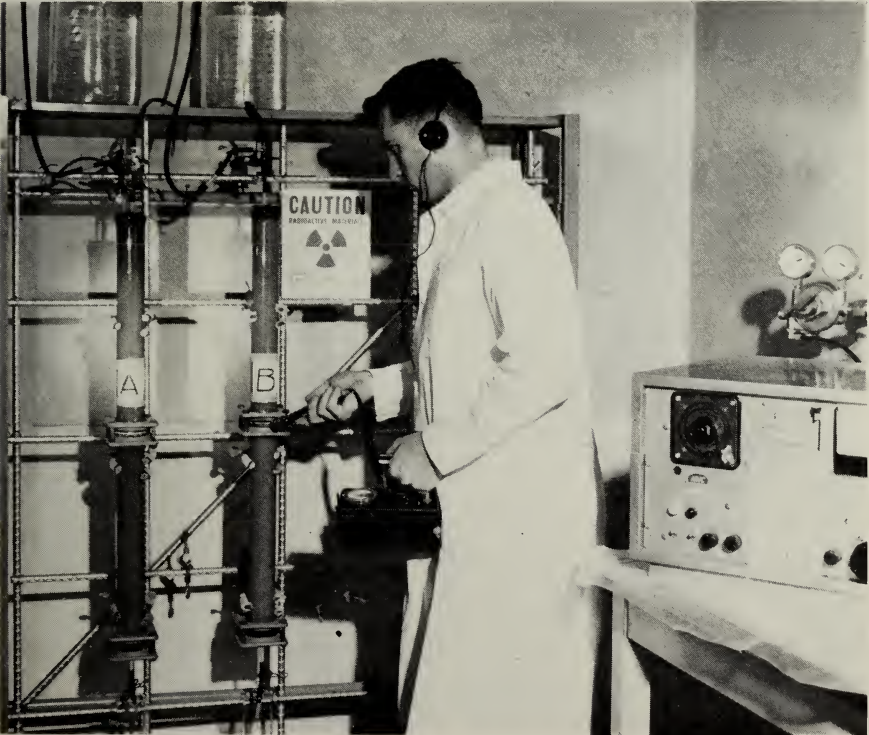
Second Semester **Units**

C.E. 355 Hydraulic Structures, II....................................¾
C.E. 356 Hydraulic Engineering Laboratory..........................¾
C.E. 458 Open-Channel Hydraulics 1
C.E. 497 Special Problems 1
          Elective...1
                                                                  ⎯
                                                                  4½

Other Courses. Special problems in hydraulic engineering or courses in other fields related to it may be substituted for some of the subjects suggested above. Special attention is called to the desirability of Theoretical and Applied Mechanics 431 and 432, and Geology 301 and 450.

RAILWAY ENGINEERING

First Semester **Units**

C.E. 333 Urban and Regional Transportation, or approved elective........1
C.E. 383 Soil Mechanics 1
*C.E. 435 Railway Construction and Maintenance......................1
C.E. 497 Special Problems, or C.E. 499 Thesis Research...............½
Econ. 484 Economics of Transportation..............................1
                                                                  ⎯
                                                                  4½

*Students not adequately prepared for this course will be required to take Civil Engineering 335 for ½ unit as a prerequisite (or concurrently).

Second Semester **Units**

C.E. 338 Terminals...1
C.E. 391 Numerical and Computer Applications in Civil Engineering.......1
*C.E. 436 Railroad Location and Operation...........................1
C.E. 485 Soil Engineering for Transportation Facilities,
          or Econ. 485 Economics of Transportation....................1
C.E. 497 Special Problems, C.E. 499 Thesis Research...................½
                                                                  ⎯
                                                                  4½

*Students not adequately prepared for this course will be required to take Civil Engineering 336 for ½ unit as a prerequisite (or concurrently).

GENERAL TRANSPORTATION

First Semester **Units**

C.E. 333 Urban and Regional Transportation..........................1
C.E. 497 Special Problems: Transportation Planning...................1
C.E. 497 Special Problems, or C.P. 372 Theory and Practice,
          or approved elective......................................1
C.E. 499 Thesis Research ....½
Econ. 484 Economics of Transportation..............................1
                                                                  ⎯
                                                                  4½

    C.E. 334 Airport Design, or C.E. 436 Railroad Location and Operation....1
    C.E. 338 Terminals...1
    C.E. 497 Special Problems: Transportation Planning.....................1
    C.E. 499 Thesis Research ....½
    Econ. 485 Economics of Transportation...............................1

                                                   4½

SANITARY ENGINEERING

First Semester   **Units**

    C.E. 345 Public Health Engineering..................................½
    C.E. 440 Theory of Water Treatment.................................1
    C.E. 441 Water Purification Laboratory and Design......................1
    Microbiol. 309 Cultivation and Properties of Microorganisms.............1
    Approved Elective, or C.E. 499 Thesis Research......................½ to 1

                                         4½ to 5

Second Semester   **Units**

    C.E. 442 Theory of Waste Water Treatment..........................1
    C.E. 443 Waste Treatment Laboratory and Design......................1
    C.E. 499 Thesis Research, or C.E. 497 Special Problems................1
    Approved Elective ....1 to 2

                                           4 to 5

    Other Courses. Approved elective may be selected from suitable courses in sanitary and civil engineering, microbiology, chemistry, mathematics, physics, and fluid mechanics.

SOIL MECHANICS

SOIL MECHANICS AND FOUNDATIONS

First Semester   **Units**

    C.E. 383 Soil Mechanics 1
    C.E. 385 Engineering Aspects of Surficial Soils.........................1
    C.E. 460 Structural Analysis, or
              C.E. 461 Structural Theory and Design........................1
    C.E. 480 Earth Pressures and Retaining Structures......................1
    Geol. 450 Geology for Civil Engineers.................................1

                                               5

Second Semester   **Units**

    C.E. 384 Applied Soil Mechanics....................................1
    C.E. 481 Earth Dams and Related Problems..........................1
    C.E. 482 Measurement of Soil Properties.............................1
    C.E. 484 Foundation Engineering 1

                                               4

First Semester   **Units**

    C.E. 383   Soil Mechanics 1
    C.E. 461   Structural Theory and Design..................................1
    C.E. 480   Earth Pressures and Retaining Structures......................1
    Geol. 450   Geology for Civil Engineers................................1
    Selected Course ....0 to 1

                                                      4 to 5

Second Semester   **Units**

    C.E. 384   Applied Soil Mechanics.....................................1
    C.E. 462   Structural Theory and Design...............................1
    C.E. 465   Structural Design in Metals.................................1
    C.E. 481   Earth Dams and Related Problems............................1
    C.E. 484   Foundation Engineering 1

                                                      5

Other Courses. Special Problems in Soil Mechanics and Structures or other courses in these and related fields may be substituted in the above programs according to the student's previous work and the objectives of his study.

STRUCTURAL ENGINEERING

A wide range of courses is available in this field, leading to specialization in reinforced concrete, structural metals, theory and analysis, structural and soil dynamics, and other areas. The student selects courses for four to five units of credit each semester, during the two or more semesters of his career, after consultation with his adviser. A well-balanced program ordinarily includes one or more units from at least four of the six following groups of courses:

1. Advanced mathematics (Mathematics 343, 345, and 395 are recommended).
2. Theoretical and applied mechanics (Theoretical and Applied Mechanics 416, 421, 441, and 451 are recommended).
3. Structural analysis (Civil Engineering 461, 462, 471, 472, 473, 474).
4. Structural design (Civil Engineering 464, 465, 468, 469, 477).
5. Behavior of structures (Civil Engineering 366, 467, and 475; Theoretical and Applied Mechanics 424).
6. Soil mechanics and foundation engineering (Civil Engineering 383, 384, and 480 to 485).

The student may round out his program with other courses in civil engineering, theoretical and applied mechanics, mathematics, or physics (especially Physics 383).

Students who are taking half-time programs of graduate study as research assistants are permitted to take three courses each semester. They ordinarily take the same type program as full-time students, but have more time available for elective subjects. However, a research assistant is required to include at least one unit of thesis research or special problems in his program for the master's degree.

Because of the wide selection of courses specific programs are not suggested here. The student is encouraged to take some courses in areas other than his specialty to provide greater depth in his program.

TRAFFIC ENGINEERING

First Semester   **Units**

    C.E. 325   Highway Traffic Characteristics............................½

    C.E. 420   Pavement Design, I..1

    C.E. 426   Traffic Planning 1

    C.E. 495   Highway and Traffic Seminar................................0

    C.E. 499   Thesis Research 1

    Psych. 306 Quantitative Methods, 1....................................1

                                        4½

Second Semester   **Units**

    C.E. 427   Geometric Highway Design..................................1

    C.E. 428   Traffic Engineering Operations..............................1

    C.E. 496   Highway and Traffic Seminar................................0

    C.E. 497   Special Problems 1

    C.E. 499   Thesis Research 1

                                        4

    Other Courses. Work in special problems listed under Civil Engineering 497, Highway and Traffic Engineering, and City Planning 372 and 488, may be substituted for certain of the courses suggested above.

ENGINEER OFFICERS PROGRAM

    The following program is a special graduate program for Army officers in the Corps of Engineers with undergraduate training at the U. S. Military Academy. It is intended to cover a broad range in civil engineering to fit the students for any phase of civil engineering, but there is an opportunity for specialization in one or two areas.

Summer Session   **Credits**

    C.E. 460   Structural Analysis (required course).......................1 unit

    C.E. 344   Water and Waste Water Treatment.........................1 unit

    and/or   Approved Electives, including T.A.M. 421,

               Mechanics of Materials, or Math. 345, Differential Equations

               and Orthogonal Functions

Four Weeks Following Summer Session   **Credits**

    C.E. 264   Reinforced Concrete Design, I............................3 hours

    C.E. 290   Contracts and Specifications.............................2 hours

Fall and Spring Semesters

    Four to five units each semester including:

1. Math. 345, if not taken previously;
2. C.E. 366 or C.E. 464;
3. C.E. 465;
4. One unit from groups A and B;
5. Two units from groups C and D.

The remaining courses should be selected with major emphasis on preferably only two of the groups of courses listed. Other courses, however, may be substituted with the approval of the faculty adviser. Other major fields of emphasis may be considered subject to final approval by the Corps of Engineers.

A. Transportation Units

C.E. 334   Airport Design ....½ to 1
C.E. 336   Railway Location and Operation..........................½ to 1
C.E. 420, 421   Pavement Design, I and II...............................2
C.E. 436   Railroad Location and Operation.............................1

B. Hydraulics, Water Supply, and Waste Water Disposal Units

C.E. 344   Water and Waste Water Treatment...........................1
C.E. 345   Public Health Engineering.................................½
C.E. 348   Air Pollution ....½
C.E. 440   Theory of Water Treatment.................................1
C.E. 441   Water Purification Laboratory and Design..................1
C.E. 442   Theory of Waste Water Treatment...........................1
C.E. 443   Waste Treatment Laboratory and Design.....................1
C.E. 444   Industrial Wastes ....½ to 1
C.E. 446   Design of Water and Waste Treatment Plants................1
C.E. 447   Radioactive Waste Disposal.............................½ to 1
C.E. 450   Advanced Hydrologic Analysis and Design...................1
C.E. 452   Water Resources Planning and Development..................1
C.E. 455   Water Power Engineering...................................1
C.E. 458   Open-Channel Hydraulics 1
T.A.M. 334   Fluid Mechanics and Advanced Hydraulics...............½ to 1

C. Structures Units

C.E. 366   Behavior of Reinforced Concrete Members...................1
C.E. 368   Prestressed Concrete ....½
C.E. 461   Structural Theory and Design..............................1
C.E. 462   Structural Theory and Design..............................1
C.E. 464   Reinforced Concrete Design................................1
C.E. 465   Structural Design in Metals...............................1
C.E. 467   Behavior of Reinforced Concrete Structures................1
C.E. 468   Analysis and Design of Prestressed Concrete Structures....1
C.E. 471   Numerical and Approximate Methods of Structural Analysis..1 to 2
C.E. 472   Advanced Numerical Methods in Engineering..............1 to 2
C.E. 473   Analysis and Design of Plates and Shells...............1 to 2
C.E. 474   Behavior of Structures Under Dynamic Loads.............1 to 2
C.E. 475   Behavior of Steel Structures..............................1
C.E. 477   Design of Structures for Dynamic Loads....................1

D. Soil Mechanics and Foundations Units

C.E. 380   Foundation Engineering 1
C.E. 383   Soil Mechanics ....¾ to 1
C.E. 384   Applied Soil Mechanics................................¾ to 1
C.E. 385   Engineering Aspects of Surficial Soils....................1
C.E. 480   Earth Pressures and Retaining Structures..................1

SPECIAL MILITARY PROGRAMS

A number of special programs for officers in the Air Force, Navy Civil Engineers Corps, and Army Corps of Engineers are available. These are based on the general program for engineer officers as outlined above, but provide for greater specialization in such fields as structural dynamics, advanced structural theory, engineering physics, and nuclear engineering. Detailed suggestions and course outlines may be obtained from the head of the department. In general, these programs require the equivalent of two years of study, or at least three semesters and one (or preferably two) summer sessions.

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Urbana, Illinois

Department of Civil Engineering
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Housing Division
108 Illini Hall
Champaign, Illinois

Office of Foreign Student Affairs
152 Administration Building (West)
Urbana, Illinois

University offices are open Monday through Friday
from 8:00 a.m. to 12:00 noon and
from 1:00 to 5:00 p.m. except on holidays.